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ABSTRACT: *In Northwest Australia fourteen species and subspecies of* Globotruncana, *ranging in age from Cenomanian or Turonian to Maestrichtian, have been found in surface and well samples from the Carnarvon Basin. Many species that are common in the European Upper Cretaceous also appear in the Upper Cretaceous of Northwest Australia, where their stratigraphic distribution is likewise of considerable value in correlation. Quantitative analysis of microfaunas containing* Globotruncana *suggests that the members of this genus are benthonic, at least in the adult stages, and not entirely planktonic as formerly supposed.*

The genus Globotruncana in Northwest Australia

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INTRODUCTION

In Northwest Australia representatives of the genus *Globotruncana* are common in the Upper Cretaceous sediments. The writer has recognized fourteen species and subspecies which have a restricted stratigraphic distribution. These are *Globotruncana contusa* (Cushman), *Globotruncana citae* Bolli, *Globotruncana elevata elevata* (Brotzen), *Globotruncana lugeoni* Tilev, *Globotruncana planata* n. sp., *Globotruncana arca* (Cushman), *Globotruncana paraventricosa* (Hofker), *Globotruncana fornicata* Plummer, *Globotruncana marginata* (Reuss), *Globotruncana lapparenti lapparenti* Brotzen, *Globotruncana spinea* Kikoine, *Globotruncana lapparenti* cf. subsp. *tricarinata* Quereau, *Globotruncana globigerinoides* Brotzen, and *Globotruncana (Rotalipora)* cf. *turonica* (Brotzen).

In addition, the species *Rugoglobigerina rugosa* (Plummer) is also described, as it occurs commonly with various *Globotruncana* species and has a morphological alliance with the *Globotruncana* group.

MATERIAL

From 1950 to 1952 the writer worked on microfossil material from the Carnarvon Basin in conjunction with a geological survey of that area conducted by the Australian Bureau of Mineral Resources. At that time, the writer was attached to the staff of that organization as a geologist. Surface samples were collected from well exposed sequences of Cretaceous strata along the west flank of the Giralia Anticline. This anticline is situated in the northern part of the Carnarvon Basin, near the head of Exmouth Gulf.

It is an eroded, gently folded structure some eighty miles in length (see text-fig. 1). Most of the material described in this paper comes from sampled stratigraphic sections in the Giralia Anticline.

Additional material comes from cable-tool samples taken in a water well drilled near the town of Carnarvon. This well, known as the Brickhouse Bore, penetrated 1200 feet of Upper Cretaceous shales and siltstones with abundant *Globotruncana*. The Brickhouse Bore section is located approximately 150 miles south of the surface sections from the Giralia Anticline and is in the central part of the Carnarvon Basin.

Some specimens of *Globotruncana* are also described from an outcrop of the Upper Cretaceous Gingin chalk. This formation outcrops sixty miles north of Perth in another marginal basin of deposition known as the Perth Basin.
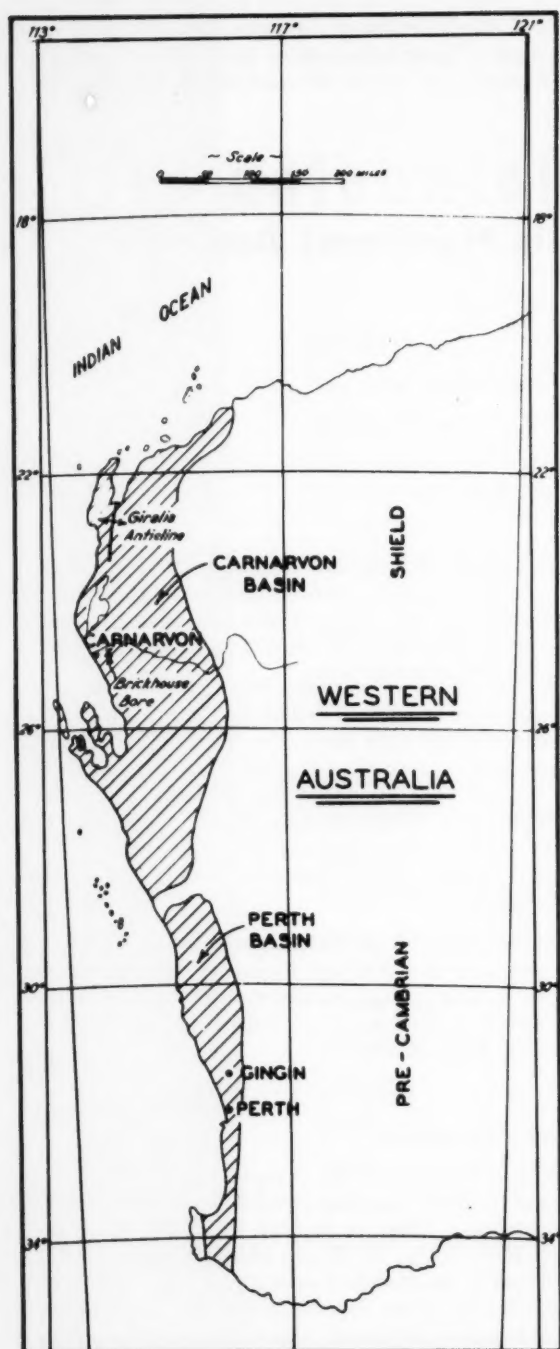
ACKNOWLEDGMENTS

TEXT-FIGURE 1
LOCALITY MAP

CRETACEOUS STRATIGRAPHY

The sequence of Cretaceous sediments in the northern part of the Carnarvon Basin has been described by Raggatt (1936), and later in more detail by Condon (1954) and by Condon, Johnstone, Prichard and Johnstone (1956). A general description of the Cretaceous stratigraphy of the Giralia Range is given here as a background to the distribution of *Globotruncana* species.
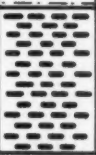
Cretaceous strata are developed to a thickness of approximately 900 feet in the Giralia Anticline and are known to thicken gradually toward the west. The basal Cretaceous beds probably belong to the upper part of the Lower Cretaceous (Albian), and consist of sandstones and siltstones. These Lower Cretaceous formations do not outcrop at the surface in the Giralia area. They are succeeded by a characteristic outcropping formation of white to ochre-coloured radiolarian siltstone known as the Windalia radiolarite. The radiolarite formation is of probable Cenomanian age, and is conformably followed by a poorly exposed grey bentonitic siltstone formation known as the Gearle siltstone. This siltstone formation is from 500 to 700 feet thick in the Giralia area and is probably Turonian in age. It is thought to be separated by a disconformity from the overlying calcarenite formation, which is referred to as the Korojon calcarenite. The Korojon calcarenite is partly Campanian and partly Maestrichtian in age. This formation contains abundant specimens of *Globotruncana* and many large *Inoceramus*. It has a local thickness of 127 feet in the Giralia Anticline. The highest formation within the Cretaceous sequence of the northern Carnarvon Basin is a four-foot bed of soft, glauconitic marl with abundant ammonites and numerous species of *Globotruncana*. This formation is known as the Miria marl, and is definitely of Maestrichtian age. A thin glauconitic greensand with a rich Paleocene microfauna concordantly overlies the Miria marl. Although these beds are concordant, a disconformity is thought to separate them. Thus, the highest part of the Maestrichtian and the Danian I (of Wicher) are possibly represented in the Giralia sequence by a depositional hiatus separating the Miria marl from the concordantly overlying Paleocene Boongerooda greensand. In the accompanying text-figure 2, the Cretaceous stratigraphy of the Giralia area in Northwest Australia is shown diagrammatically, with indications of the field measurements of Condon, Johnstone, Prichard and Johnstone (1956).

In the central part of the Carnarvon Basin, about 150 miles south of the Giralia Anticline, the generalized Upper Cretaceous sequence is known in the

EUROPEAN STAGES	FORMATION	THICK-NESS	STRATAL COLUMN	LITHOLOGY	CHARACTERISTIC MICROFOSSILS
MAESTRICHTIAN	Miria Marl	4'		brown, glauconitic, ammonite marl.	Glt. contusa, Glt. citae, Bolivinoides draco draco, Pseudotextularia varians.
CAMPANIAN	Korojon Calcarenite	127'		white, friable, shelly calcarenite & coquinite	Glt. fugeoni, Glt. arca, Bolivinoides decorata, Rugoglobigerina rugosa Glt. lapparenti var.
TURONIAN	Gearle Siltstone	535'		grey, bentonitic siltstone & claystone with gypsum and nodular barytes.	Ammobaculites fisheri, Gaudryinella irregularis Haplophragmoides sp. Spiroplectammina sp. Vaginulina cf. recta
CENOMANIAN	Windalia Radiolarite	100'		white to ochre-colored porcellaneous chert and radiolarian siltstone.	Ammobaculites fisheri Haplophragmoides sp. Frondicularia sp. Cenosphaera sp. Dictyomitra australis Lithocyclia exilis
ALBIAN TO APTIAN	Muderong Shale	40'		grey, gypsiferous shale and siltstone.	Ammobaculites fisheri Haplophragmoides sp.
	Birdrong Formation	97'		greenish, glauconitic sandstone and siltstone.	

TEXT-FIGURE 2
CRETACEOUS STRATIGRAPHY OF THE GIRALIA ANTICLINE

Brickhouse Bore. This water bore penetrated to a depth of about 1470 feet. The Brickhouse section is more argillaceous than the surface section in the Giralia area. The generalized sequence in the Brickhouse Bore, as shown by cable-tool samples, consists of a thin basal sandstone bed overlain by more than a thousand feet of grey shale and siltstone with occasional intercalations of marl. These strata cover the interval from the Turonian through the Campanian. The uppermost Upper Cretaceous does not appear to be represented in this bore, and Tertiary and post-Tertiary sediments occur from the surface down to a depth of 280 feet.

A few samples containing specimens of *Globotruncana* were also available to the writer from the Gingin area, about sixty miles north of Perth. The section at Gingin consists of only 70 feet of Upper Cretaceous chalk underlain and overlain by almost barren greensand formations. This outcrop of Cretaceous strata lies within another basin of deposition, referred to as the Perth Basin, but it can also be correlated with strata in the Carnarvon Basin.

SAMPLED SECTIONS

In the northern part of the Carnarvon Basin, numerous sampled sections of Cretaceous strata have been examined by the writer. Comparison of the occurrences of *Globotruncana* in these sampled sections provides a basis for local correlation as well as an evaluation of the vertical ranges of various species and subspecies.

In the Giralia area the following sections were sampled along the western limb of the Giralia Anticline: (1) North Giralia section, near White Hill; (2) Remarkable Hill section; and (3) C. Y. Creek section.

From the Brickhouse Bore near Carnarvon, cable-tool samples were also examined at twenty-foot intervals from a thickness of approximately 1200 feet of Cretaceous strata. Because of the type of sample available from this well, only the top occurrences of *Globotruncana* species are stratigraphically reliable.

Up to 1956, eighteen more wells had been drilled in the Carnarvon Basin by the West Australian Petroleum Pty., Ltd., and by the Bureau of Mineral Resources, since the time when the writer worked in that area. There is, therefore, considerable material for a comprehensive survey of the local Cretaceous microfaunas. Since this material is unavailable to the writer, it is hoped that other Australian micropaleontologists will supplement this paper on the forms of *Globotruncana* in Northwest Australia.

VERTICAL DISTRIBUTION OF SPECIES

The vertical ranges of species and subspecies of *Globotruncana* in Northwest Australia are illustrated in text-figure 3. The ranges given in this figure are based on the Brickhouse Bore samples for the lower part of the Upper Cretaceous and on surface samples from the Giralia Anticline for the upper part of the Upper Cretaceous. Correlation between these two sections has been based on the stratigraphically restricted ranges of *Bolivinoides* species (Edgell, 1954).

The generalized vertical sequence, in ascending stratigraphic order, of various forms of the genus *Globotruncana* in Western Australia appears to be as follows:

1) *Globotruncana (Rotalipora)* cf. *turonica* (Brotzen): Cenomanian to Turonian (Brickhouse Bore, depth 1210 feet);

2) *Globotruncana spinea* Kikoine: Santonian (Gingin chalk, Perth Basin);

3) *Globotruncana globigerinoides* Brotzen: Santonian to Campanian (Brickhouse Bore, depth 455 feet to 1100 feet);

4) *Globotruncana lapparenti lapparenti* Brotzen: Santonian to Campanian (Gingin chalk, Perth Basin; Brickhouse Bore, depth 995 feet to 1015 feet; base of Korojon calcarenite, Giralia Anticline);

5) *Globotruncana lapparenti* Brotzen cf. subsp. *tricarinata* (Quereau): Santonian to Campanian (Brickhouse Bore, depth 1000 feet; base of Korojon calcarenite, Giralia Anticline);

6) *Globotruncana fornicata* Plummer: Santonian to Campanian (Brickhouse Bore, depth 715 feet to 1135 feet);

7) *Globotruncana marginata* (Reuss): Campanian and ? Santonian (Brickhouse Bore, depth 615 feet to 855 feet);

8) *Globotruncana paraventricosa* (Hofker): Campanian (Brickhouse Bore, depth 435 feet; base of Korojon calcarenite, Giralia Anticline);

9) *Globotruncana lugeoni* Tilev: Campanian and Maestrichtian (Korojon calcarenite, Giralia Anticline);

10) *Globotruncana arca* (Cushman): Campanian and Maestrichtian (Brickhouse Bore, depth 280 feet to 1055 feet; Korojon calcarenite and Miria marl, Giralia Anticline);

11) *Globotruncana planata* n. sp.: Maestrichtian (Miria marl, Giralia Anticline);
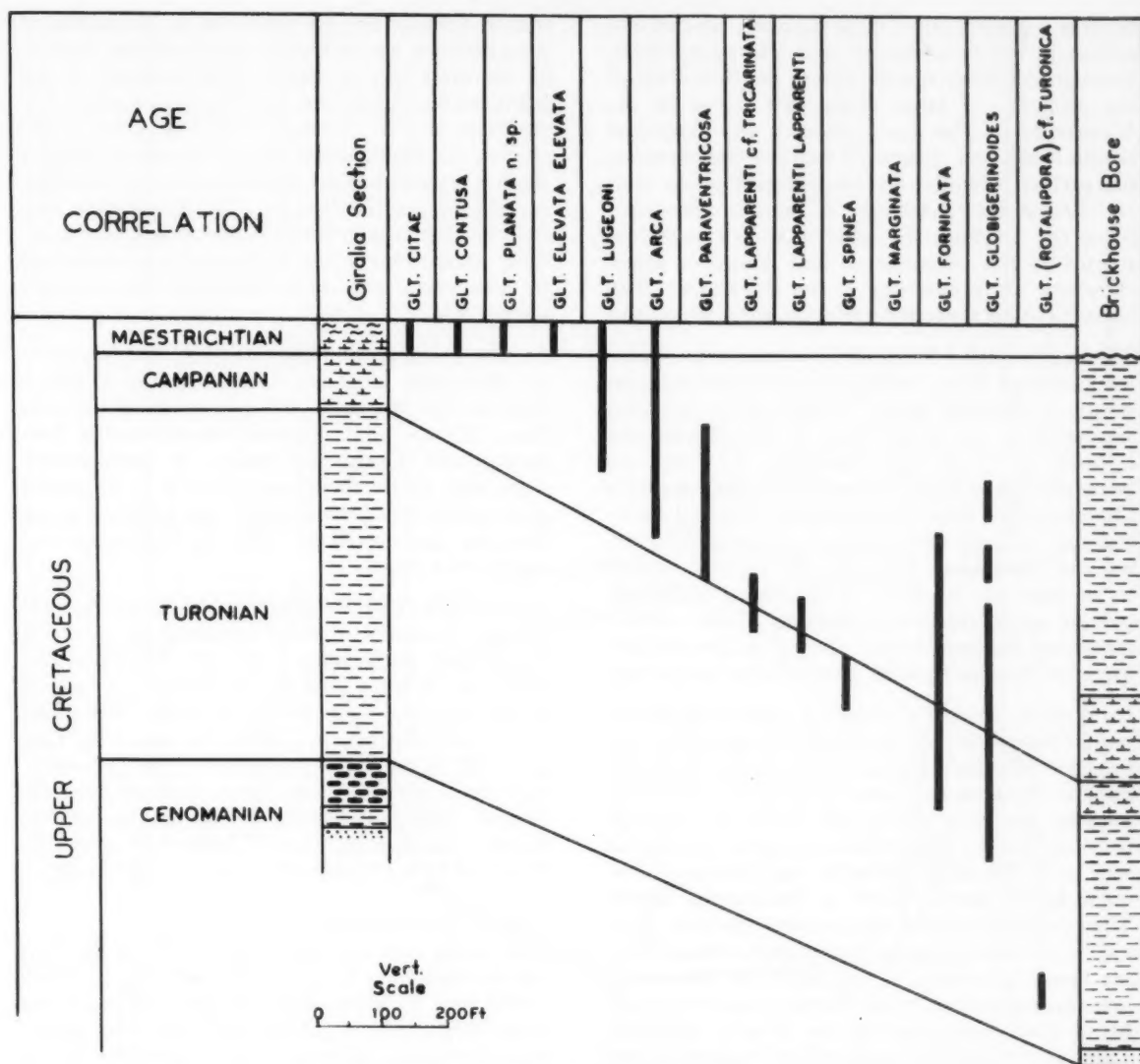
TEXT-FIGURE 3

STRATIGRAPHIC DISTRIBUTION OF FORMS OF GLOBOTRUNCANA IN PARTS OF NORTHWEST AUSTRALIA

12) *Globotruncana elevata elevata* (Brotzen): Maestrichtian (Miria marl, Giralia Anticline);

13) *Globotruncana contusa* (Cushman): Maestrichtian (Maria marl, Giralia Anticline);

14) *Globotruncana citae* Bolli: Maestrichtian (Miria marl, Giralia Anticline).

As shown in text-figure 3, the vertical ranges of many of these species and subspecies overlap. The writer believes that examination of more complete stratigraphic sections, made available by recent

drilling in the Carnarvon Basin, will add considerably to the number of species and the generalized vertical distributions given in this paper.

CORRELATION BASED ON GLOBOTRUNCANA

Numerous recent publications have dealt with the detailed stratigraphic distribution of the forms of *Globotruncana* in widely separated parts of the world. In this way the stratigraphic value of species and subspecies of *Globotruncana* for interregional correlation of Upper Cretaceous strata has become generally accepted. Within the Upper Cretaceous alone

there is a general trend from primitive unicarinate species in the Cenomanian and Turonian stages, through bicarinate species during the Senonian, to the evolution of large unicarinate forms in the Maestrichtian. This development is also illustrated by the Northwest Australian forms of *Globotruncana*, the earliest of which are single-keeled forms such as *Globotruncana (Rotalipora)* cf. *turonica* (Brotzen). Since the subgenus *Rotalipora* is known to be restricted to the Cenomanian and Turonian stages elsewhere, its occurrence in the Brickhouse Bore below 1210 feet suggests correlation with these stages.

The double-keeled forms of *Globotruncana* are dominant amongst all succeeding Cretaceous microfaunas in the Carnarvon Basin. Where no single-keeled species occur and where forms of the *Globotruncana lapparenti* group are most abundant, the strata are generally earlier than Maestrichtian and later than Cenomanian. Other double-keeled species of *Globotruncana*, namely *Globotruncana globigerinoides* Brotzen and *Globotruncana marginata* (Reuss), also appear to be restricted to strata of Santonian and Campanian age in Northwest Australia. These vertical ranges are comparable with those given for the same species in Europe by Bolli, Cita, Hofker and others.

In Western Australia, strata of uppermost Cretaceous (Maestrichtian) age can be recognized by the presence of certain distinctive single-keeled species such as *Globotruncana contusa* (Cushman) and *Globotruncana citae* Bolli. These two species are likewise restricted to the Maestrichtian stage in Europe as well as in Trinidad, Colombia and Mexico. A few single-keeled species, such as *Globotruncana lugeoni* Tilev and *Globotruncana elevata elevata* (Brotzen) have a more extended range in Northwest Australia. They are found in strata of Campanian and Maestrichtian age, represented by the Korojon calcarenite and Miria marl formations of the Giralia Anticline. These species are also restricted to Campanian and Maestrichtian strata in Turkey, Palestine and central Europe.

COMPARATIVE CORRELATION BASED ON OTHER FORAMINIFERA

Many other well known index species for parts of the Upper Cretaceous are associated with the forms of *Globotruncana* occurring in Northwest Australia. Independent correlations based particularly on species of the genera *Bolivinoides*, *Neoflabellina*, *Pseudotextularia* and *Stensiöina* provide a check on the vertical distribution of *Globotruncana* species in the Carnarvon Basin.

Thus, the species *Bolivinoides draco draco* (Marsson), *Neoflabellina reticulata* (Reuss), and *Pseudotextularia*

varians Rzehak are all restricted to sediments of Maestrichtian age in Europe. In Northwest Australia the same species appear to be confined to the Miria marl and Korojon calcarenite formations. On the basis of the distribution of these three guide species, this stratigraphic interval in the Carnarvon Basin is regarded as Maestrichtian in age. As *Globotruncana contusa* (Cushman) and *Globotruncana citae* Bolli are confined to the same stratigraphic interval, their Maestrichtian age in Australia is confirmed by association with other restricted Maestrichtian microfossils.

Another comparative correlation is that provided by *Bolivinoides strigillata* Chapman, which occurs between 995 feet and 1055 feet in the Brickhouse Bore. This species of *Bolivinoides* is restricted to Santonian and Campanian strata in northwestern Germany. In the Brickhouse Bore it is associated with subspecies of the *Globotruncana lapparenti* group that are also correlated with the Santonian and Campanian stages.

The Gingin chalk formation in the Perth Basin of Western Australia contains numerous specimens of *Neoflabellina interpunctata* (von der Marck). This species is an index fossil for the Santonian stage in northern Europe as shown by the work of Wedekind (1940) and Hiltermann (1952). The age of the Gingin chalk is therefore considered to be Santonian. Specimens of *Globotruncana spinea* Kikoine from the Gingin chalk are likewise Santonian in age. In Europe *Globotruncana spinea* Kikoine was originally described from younger strata, of Campanian age.

MEGAFAUNAL CORRELATION

Megafossils from the Cretaceous strata of the Carnarvon Basin have been studied principally by Spath (1940) and by Brunnschweiler (see Condon, Johnstone, Prichard and Johnstone, 1956). The uppermost Cretaceous Miria marl formation of the Giralia area contains abundant ammonites in association with species of *Globotruncana*. The species *Globotruncana contusa* (Cushman) and *Globotruncana citae* Bolli range throughout this four-foot-thick marl formation, which is therefore considered to be Maestrichtian on the basis of microfossils. Spath also considers the age of the Miria marl to be Maestrichtian on the basis of ammonites. Brunnschweiler concludes that this thin marl bed is partly lower Maestrichtian and partly upper Campanian in age.

Some of the ammonites identified from the Miria marl are:

Upper part ("lower Maestrichtian") –
    Diplomoceras cylindraceum (Defrance)
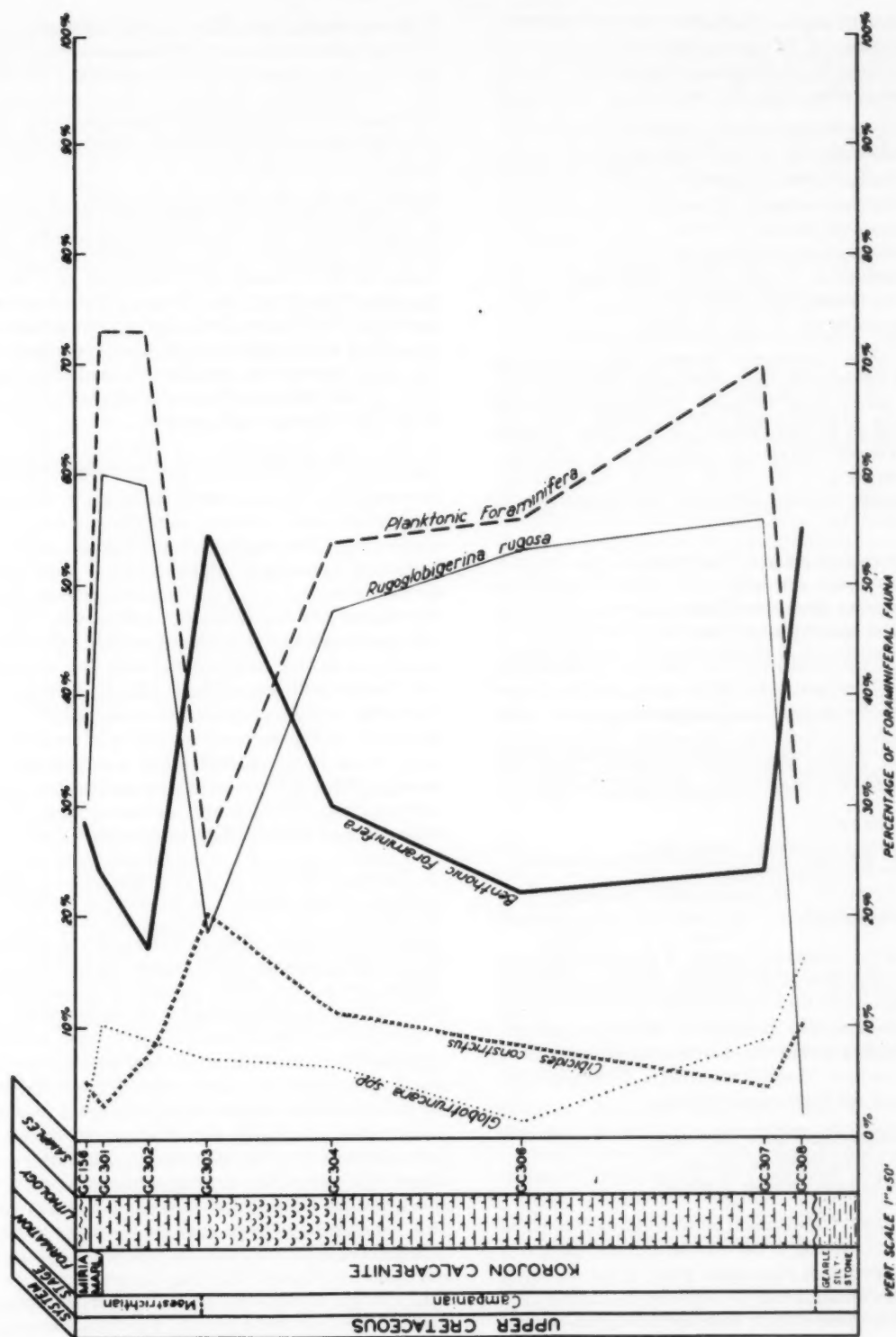
TEXT-FIGURE 4

VARIATION IN THE PERCENTAGE FREQUENCY OF GLOBOTRUNCANA IN RELATION TO THE MAJOR BIONOMIC GROUPS

Eubaculites vagina (Forbes)
Pachydiscus cf. *P. egertoni* (Forbes)
Pachydiscus cf. *P. fresvillensis* Seunes
Pseudophyllites indra (Forbes)

Lower part ("upper Campanian") –
Desmophyllites cf. *D. larteti* (Seunes)
Eubaculites vagina (Forbes)
Gandryceras varagurense Kossmat
Glyptoxoceras indicum (Forbes)
Kossmaticeras (Gunnarites) sp.
Pachydiscus cf. *P. ootacodensis* (Stoliczka)
Paraphylloceras surya (Forbes)
Tetragonites cf. *T. cala* (Forbes)

There is close agreement between the correlation based on microfossils and that based on megafossils from the Miria marl. However, the entire formation is regarded as Maestrichtian by the writer because of the occurrence of species and subspecies of foraminifera identical with those found only in the Maestrichtian elsewhere. These microfossil species nclude:

Globotruncana contusa (Cushman)
Globotruncana citae Bolli
Bolivinoides draco draco (Marsson)
Pseudotextularia varians Rzehak

On megafossil evidence, the Korojon calcarenite, immediately beneath the Miria marl, has been considered to be Santonian and perhaps also early Campanian (see Condon, Johnstone, Prichard and Johnstone, 1956). Megafossils identified from this formation by Brunnschweiler are listed below:

Baculites sp.
Bostrychoceras indicum (Stoliczka)
Desmoceras (Latidorsella?) sp.
Hauericeras sp. *(H. pseudogardeni* (Schluter)?)
Puzosia sp. indet.

In view of the indefinite nature of these cephalopod identifications from the Korojon calcarenite, there appears to be a rather inadequate basis for definite correlation with the Santonian. Microfossil identifications indicate that the Korojon calcarenite is of Campanian and Maestrichtian age. The upper 20 to 25 feet of the formation contain:

Bolivinoides draco draco (Marsson)
Neoflabellina reticulata (Reuss)
Pseudotextularia varians Rzehak

In the Upper Cretaceous of Europe, all of these species are restricted to the Maestrichtian stage, and their occurrence in the upper part of the Korojon calcarenite would seem to indicate a similar correlation for these strata. The single-keeled species

Globotruncana lugeoni Tilev occurs throughout the Korojon calcarenite, and *Globotruncana arca* (Cushman) is also common in this formation. These species of *Globotruncana* suggest a Campanian age for the lower 100 feet of the Korojon calcarenite rather than the Santonian correlation based on megafossil genera.

Strata of definite Santonian age are known at Gingin in the Perth Basin. The Gingin chalk contains the crinoids *Uintacrinus* and *Marsupites*, as well as *Ostrea vesicularis* Lamarck, *Parapuzosia* sp., *Micraster* sp., and *Holaster* sp. The forms of *Globotruncana* occurring in the Gingin chalk also support a Santonian age. They are *Globotruncana lapparenti lapparenti* Brotzen and *Globotruncana marginata* (Reuss). This association of *Globotruncana* species is definitely older than that of the Korojon calcarenite.

PALEOECOLOGY OF MICROFAUNAS WITH GLOBOTRUNCANA

An attempt has been made to analyse the paleoecology of a succession of microfaunal assemblages containing *Globotruncana*. Naturally the deductions from such an analysis are tentative, as none of these Cretaceous species can be found in present-day living foraminiferal assemblages. However, the ecological limitations of closely related genera and species are known from the works of Lowman, Phleger, Parker and others. In addition, the writer believes that certain general relationships between the benthonic and planktonic elements of a microfauna may be of value in indicating water depth in a broad, stable shelf type of marine environment. Concurrent investigations of sedimentology, detrital minerals and foraminifera by Carozzi (1949, 1953) have shown a general numerical increase or decrease of planktonic foraminifera with deeper or shallower conditions, respectively.

Samples collected from a well exposed measured stratigraphic section of the Upper Cretaceous in the Giralia area have been examined quantitatively. Approximately 300 specimens of foraminifera from a standard volume of each sample were identified specifically. In this way the percentage of the microfauna constituted by each species could be determined. A graph similar to text-figure 4 was then constructed, in which the abscissa represents the percentage of the total microfauna, and the ordinate shows the ascending stratigraphic succession and the locations of samples examined quantitatively. If a benthonic species, such as *Cibicides constrictus* (Hagenow), is considered in successive samples, a curve can be drawn showing the percentage which this species constitutes in successive microfaunal assemblages (see text-figure 4). For the same samples

a percentage curve for a planktonic species, such as *Rugoglobigerina rugosa* (Plummer), can also be constructed.

It will be seen from these two curves that the percentage abundance of a planktonic species varies inversely with that of a benthonic species. This is even more clearly shown when the percentage of total planktonic foraminifera is plotted and compared with a similar graph of the percentage of total benthonic foraminifera for each sample.

This inverse variation in the abundance of planktonic and benthonic species is taken as an indication of variation in water depth. Thus, where benthonic foraminifera are most abundant and where pelagic forms are most rare, the conditions of deposition may have been near shore and in shallow water. However, the flooding abundance of planktonic foraminifera associated with a paucity of benthonic forms may indicate a deep-water, open-ocean environment in which adverse light, temperature, and food-supply conditions inhibited the development of benthonic species. This variation in the percentage frequency of bionomic groups has perhaps an application to the study of the genus *Globotruncana*. When the percentage abundance of all *Globotruncana* species in the samples examined is plotted as a graph, it is found that this graph closely resembles that for a benthonic species. In other words, *Globotruncana* is abundant where other benthonic genera (such as *Anomalina* and *Cibicides*) are abundant. It is not so frequent where thin-shelled, planktonic species of *Globigerina* and *Rugoglobigerina* are most common. Quantitatively, *Globotruncana* behaves like a benthonic form.

Further confirmation of the benthonic nature of *Globotruncana* is given by the morphology of the test. Most species of this genus have a heavy type of shell with beaded sutures and carinae. They also possess a complex umbilical plate with numerous accessory apertures from which the protoplasm of the living test may have exuded over some substratum.

In almost all recent works, *Globotruncana* has been regarded as a planktonic genus, and the widespread distribution and correlative value of its species have been largely attributed to its planktonic nature. The writer contends that most adult forms of *Globotruncana* were probably benthonic. However, the initial globigerinid chambers of the genus may represent a young stage which was truly planktonic. This hypothesis would account for the widespread distribution of many species of *Globotruncana* and also for regional differences in the gerontic forms of these species.

SYSTEMATIC DESCRIPTIONS

The systematics, morphology, and phylogeny of the species and subspecies of *Globotruncana* found in Northwest Australia are discussed briefly below. The specimens figured in the accompanying plates are to be deposited as types in the collections of the Bureau of Mineral Resources, Canberra, Australia.

Order FORAMINIFERA

Family ROTALIIDAE

Genus **Globotruncana** Cushman, 1927

Test trochoidally coiled, perforate, vitro-calcareous, generally ornamented with pustules and carinae. Umbilicus open, usually more or less covered by lamellar expansions. Principal aperture interiomarginal to umbilical, often with accessory apertures.

Two subgenera of the genus *Globotruncana* are recognized in Northwest Australia. These are *Rotalipora* and *Globotruncana* s. str. In the subgeneric division of *Globotruncana*, the writer has followed the system established by Reichel (1950). The systematics of Hofker (1956) are not employed because they are based primarily on the interpretation of apertures alone and because very similar species are separated even into different genera.

Subgenus **Rotalipora** Brotzen, 1942

Single marginal keel; principal aperture interiomarginal to umbilical; accessory apertures present in the sutural furrows of the last chambers.

Globotruncana (Rotalipora) cf. **turonica** (Brotzen)
Plate 1, figures 16–18

Rotalipora turonica BROTZEN, 1942, Sver. Geol. Unders., ser. C, no. 451, p. 32, text-fig. 10.

Material: A single well-preserved specimen from the Brickhouse Bore is described and figured here.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Type no. 1978.

Diagnosis: Shallowly biconvex, single-keeled; coiling depressed trochoid. Outline lobate, chambers inflated on both dorsal and ventral sides. Dorsal sutures depressed. Ventral sutures also depressed and radial, but with arched sutural apertures. Umbilicus wide and shallow with a covering plate extending between the inner edges of the sutural openings.

Description: The test is lenticular in shape, being coiled in a shallow trochoid spire. The dorsal side is moderately convex and is composed of three whorls of chambers.

There are six chambers in the last whorl; these chambers are large and slightly inflated, with a polyhedral shape. The chambers of the first two whorls are very strongly inflated and globular, so that this portion of the test is quite globigerinoid. The dorsal sutures are all depressed, those of the last whorl being somewhat oblique. In outline, the test is moderately lobate, with a smooth, more or less marked keel around the periphery. On the first two chambers of the last whorl the keel is beaded.

The chambers of the ventral side are more inflated than those of the dorsal side, and the sutures between them are radial and depressed. The ventral surfaces of the earlier chambers are rugose. The umbilicus is shallowly depressed, with a plate-like covering. On each of the ventral sutures, near the umbilicus, there are distinct, arched apertures, each with a slightly projecting lip. These secondary apertures face in the opposite direction from the large, arched, interiomarginal aperture of the last chamber.

Remarks: This form is closely allied to *Globotruncana (Rotalipora) turonica* (Brotzen). It differs from the type figure given by Brotzen (1942) in having more oblique sutures on the dorsal side and a less lobate outline. In these characters the Australian species resembles *Globotruncana (Rotalipora) cushmani* (Morrow) from the Gulf Coast of North America. The first two whorls are distinctly like *Globigerina*, and it appears that the *Rotalipora* characteristics are restricted to the final whorl. This feature suggests the globigerinid ancestry of *Rotalipora*, and because it extends through several whorls, it is not considered to be merely the homeomorphic globigerinoid initial stage that is common to many different genera. As noted by Reichel (1950), it is probable that *Globotruncana alpina* Bolli, 1945, is a synonym of *Globotruncana (Rotalipora) turonica* (Brotzen).

Dimensions: Diameter 0.4 mm.

Occurrence: In the Carnarvon Basin, Northwest Australia, this species was found only rarely in samples from the Brickhouse Bore at a depth of 1210 feet. Here it is associated with a rich radiolarian fauna, with arenaceous foraminifera, and with *Globigerina planispira* Tappan, 1940. The subgenus *Rotalipora* is restricted to the Cenomanian and Turonian stages in Europe, and its occurrence in Northwest Australia suggests a correlation with strata of this age.

Subgenus **Globotruncana** Cushman, s. str. Reichel, 1950

Subgenotype: Globotruncana arca Cushman, 1927.

Subgeneric description: Test trochospiral with limbate and generally beaded sutures. Initial chambers globigerinoid; later chambers typically with double-keeled and truncated periphery, but geologically earlier and later species are unicarinate. Chambers globular or polyhedral with no direct intercommunication. Principal aperture usually opens only into a wide umbilicus, but may be partly marginal in primitive forms. Perforate plate often covering umbilicus, but with marginal apertures in the form of arches or slight tubular projections. Shell calcareous, finely perforate except for beaded sutures and carinae. Surface often rugose.

Distribution: Cenomanian to Maestrichtian.

Relationships and differences: Globotruncana s. str. differs from *Globigerina* in having a peripheral keel or keels, limbate sutures, and an umbilical plate. However, a very similar plate is present in *Rugoglobigerina*, and most forms of *Globotruncana* possess a globigerinoid initial stage. In addition, certain of the latter species, such as *Globotruncana marginata* (Reuss) and *Globotruncana globigerinoides* Brotzen, have globular chambers fully corresponding with those of *Globigerina* except for the presence of indistinct peripheral keels.

Globotruncana s. str. appears more closely related to *Globigerina*, particularly *Rugoglobigerina*, than to *Planulina*, *Anomalina* and *Pseudovalvulineria* as suggested by Brotzen (1942) and Reichel (1950). In *Globorotalia* the presence of a terminal aperture, communicating chambers, and a narrow umbilicus, as well as the absence of limbate, beaded sutures, a double keel, and umbilical plates, clearly separates it from *Globotruncana*.

Globotruncana (Globotruncana) arca (Cushman)
Plate 1, figures 10–12; plate 3, figures 4–6

Pulvinulina arca CUSHMAN, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, p. 23, pl. 3, fig. 1a–c.
Rosalinella rugosa MARIE, 1941, Paris, Mus. Nat. Hist. Nat., Mém., new ser., vol. 12, p. 241, pl. 35, fig. 340a–c.
Globotruncana arca (Cushman) subsp. *arca* (Cushman). – GANDOLFI, 1955, Bull. Amer. Pal., vol. 36, no. 155, pp. 63–64, pl. 5, figs. 2a, 2c, 3a–c (not fig. 4a–c).

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Types no. 1979, 1980, 1999.

Description: Unequally biconvex, moderately convex dorsally, almost flat ventrally. Nearly constant angle between slopes of dorsal and ventral sides. Strongly bicarinate with narrow, inclined carinal band. Six to eight chambers on dorsal side, petaloid in shape. Chambers on ventral side outlined by strong, horseshoe-shaped ridges which do not overlap. Umbilicus wide, sometimes with umbilical plate and surrounding umbilical apertures.

Remarks: Many of the Australian specimens appear identical with Cushman's type figure, or with those given by Glaessner (1945, text-fig. 33).

Considerable confusion has arisen between *Globotruncana arca* (Cushman) and other species because Cushman (1946) illustrated a single-keeled form under this name. As pointed out by Bolli (1951), the unicarinate form figured by Cushman (1946) in pl. 62, fig. 5a–c, is probably *Globotruncana stuarti* (de Lapparent). There is sometimes a reduction of the ventral peripheral keel in the later chambers of *Globotruncana arca* (Cushman) (see pl. 1, fig. 12).

Globotruncana arca (Cushman) can be readily distinguished in profile from other somewhat similar species with two marginal keels. Thus, *Globotruncana lapparenti lapparenti* Brotzen is flat dorsally and ventrally, *Globotruncana lapparenti bulloides* Vogler has inflated chambers, and *Globotruncana lapparenti tricarinata* (Quereau) has a prominent third ventral keel and is flatter dorsally. All members of the *Globotruncana lapparenti* group have a more or less vertical carinal band, whereas the carinal band is inclined in *Globotruncana arca* (Cushman). The latter species is generally domed dorsally and almost flat ventrally, with no prominent third keel and without inflated chambers.

Dimensions: Diameter 0.5 mm.; thickness 0.2 mm.

Occurrence: In Northwest Australia this species is common in beds of Maestrichtian and Campanian age. It occurs in the Korojon calcarenite and Miria marl formations in the Giralia Anticline, as well as in the Brickhouse Bore from 280 feet to 1055 feet. The occurrences of *Globotruncana arca* (Cushman) in Northwest Australia do not appear to be limited to beds of Maestrichtian age as noted by Bolli (1951) in Trinidad.

Globotruncana (Globotruncana) citae Bolli
Plate 1, figures 13–15

Globotruncana citae BOLLI, 1951, Jour. Pal., vol. 25, p. 197, pl. 35, figs. 4–6.
?Globorotalia pshadae KELLER, 1946, Bull. Soc. Nat. Moscou, new ser., vol. 51, no. 3, pp. 99, 108, pl. 2, figs. 4–6.
Marginotruncana citae (Bolli). – HOFKER, 1956, Neues Jahrb. Geol. Pal., Abh., vol. 103, no. 3, p. 334, text-fig. 25.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Type no. 1981.

Description: Strongly lobate in outline. Shell small, very compressed, shallowly convex dorsally and flat to concave ventrally. A single weakly developed marginal keel or a row of small spines. Sutures slightly curved on the dorsal side; ventral sutures radial, depressed. Last whorl with four or five chambers. Aperture a small arch on inner ventral side of last-formed chamber. Umbilicus small and shallow, without umbilical plate. Surface of shell finely rugose to hispid.

Remarks: Topotype specimens of *Globotruncana citae* Bolli from Trinidad kindly provided by Bolli are almost identical with those described and figured here from the uppermost Cretaceous of Northwest Australia. This species is not a typical *Globotruncana*, as it lacks the characteristic raised, beaded sutures as well as an umbilical plate, and the aperture is interiomarginal rather than umbilical. Despite extensive well preserved material, the writer has found no evidence of the accessory umbilical apertures described by Küpper (1956). *Globotruncana citae* Bolli is more thin-shelled and has finer pores than other species of *Globotruncana*.

Dimensions: Diameter 0.37 mm.; maximum thickness 0.10 mm.

Occurrence: In Northwest Australia *Globotruncana citae* Bolli has been found only in the Miria marl. This formation is only about four feet thick in the Giralia Anticline, and is of Maestrichtian age, with abundant Maestrichtian ammonites. In Trinidad, Austria, and Germany this species is also recorded only from Maestrichtian strata.

Globotruncana (Globotruncana) contusa (Cushman)
Plate 2, figures 10–12; plate 3, figures 7–9;
plate 4, figures 1–3

Pulvinulina arca Cushman var. *contusa* CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 1, p. 23.
Globotruncana conica White var. *plicata* WHITE, 1928, Jour. Pal., vol. 2, no. 4, pp. 285–286, pl. 38, fig. 8a–c.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Types no. 1982, 1983, 1984.

Description: Shell high-spired, strongly domed dorsally. Ventral side flat or concave. Two narrowly separated marginal keels; upper keel more conspicuous. Outline of test lobate to polygonal. Chambers on dorsal side narrow and elongated in direction of coiling. Dorsal sutures raised, beaded, and almost tangential. Connection of depressed chambers in successive whorls may cause plications in dorsal surface of the shell, leading to a polygonal outline. Last whorl with four to six chambers. Ventral sutures slightly curved. Horseshoe-shaped ridges outline the chambers on the ventral side. Umbilicus wide, covered by a perforated plate in well preserved specimens.

Remarks: There is considerable variation in the dorsal convexity of this species, as well as in the regularity of its outline. Specimens of *Globotruncana contusa* (Cushman) from Trinidad and Colombia are usually much more lobate than those common in Northwest Australia, and the difference is probably subspecific or varietal. Troelsen (1955) has figured under this name specimens that are almost identical with those from the Carnarvon Basin.

Globotruncana contusa (Cushman) differs from most other species of the genus in its strong dorsal convexity. It is distinguished from *Globotruncana conica* White by the possession of two keels rather than one, by its greater dorsal convexity, and by having more elongate chambers. It differs from *Globotruncana fornicata* Plummer in its much greater dorsal convexity and in having more chambers and a narrower carinal band. *Globotruncana contusa* (Cushman) was probably derived from the earlier *Globotruncana fornicata* Plummer, as pointed out by Bolli (1951). The relationship to *Globotruncana caliciformis* (de Lapparent) is uncertain, as the latter species was described only on the basis of a single vertical section.

Dimensions: Diameter 0.50 mm.; maximum height 0.35 mm.

Occurrence: In the Carnarvon Basin of Northwest Australia *Globotruncana contusa* (Cushman) is confined to the Miria marl, of Maestrichtian age.

Globotruncana (Globotruncana) elevata elevata
(Brotzen)
Plate 4, figures 4–6

Rotalia elevata BROTZEN, 1934, Zeitschr. Deutsch. Ver. Palästinas, vol. 57, p. 66, pl. 3, fig. c.
Globotruncana andori DE KLASZ, 1953, Geol. Bavarica, no. 17, pp. 233–235, pl. 6, fig. 1a–c.
Globotruncana elevata (Brotzen) subsp. *elevata* (Brotzen). – DALBIEZ, 1955, Micropaleontology, vol. 1, no. 2, p. 169, textfig. 9a–c.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Type no. 1985.

Description: Shell planoconvex, dorsal side almost flat, ventral side strongly inflated. Single-keeled, with a slightly lobate periphery. These is a characteristic central dorsal knob. Chambers on the dorsal side in a rosette pattern, six to eight in the last whorl, separated by prominent, raised, beaded sutures. The outer margin of the deepened ventral side makes an angle of 60° to 90° with the dorsal side. Umbilicus moderately large and deep.

Remarks: Specimens of this species from Northwest Australia possess the characteristic raised central knob and numerous petaloid chambers on the dorsal side. The angle between the dorsal surface and outer sides of the ventral chambers is always less than 90° and not so high as in specimens from Austria or in those figured by Knipscheer (1956) from Bavaria. In the type figure given by Brotzen (1934), this marginal angle is also less than 90°. In the earlier chambers of some specimens there is a tendency toward a doubtful second keel. Larger gerontic specimens express the typical characters of *Globotruncana elevata elevata* (Brotzen).

Dimensions: Diameter 0.4 mm. to 0.6 mm.; height 0.25 mm.

Occurrence: This species is rare to frequent in its occurrence in the Miria marl of the Giralia Range, Northwest Australia. It appears to be restricted to this formation, which is Maestrichtian in age. In Tunisia and Bavaria, *Globotruncana elevata elevata* (Brotzen) occurs only in Campanian strata. The Australian specimens possess some characters transitional to *Globotruncana falsostuarti* Sigal.

Globotruncana (Globotruncana) fornicata Plummer
Plate 3, figures 10–12

Globotruncana fornicata PLUMMER, 1931, Univ. Texas Bull. no. 3101, p. 198, pl. 13, figs. 4–6.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Type no. 1986.

Description: Test moderately convex dorsally, double-keeled, carinal band narrow and inclined. Ventral marginal keel less prominent. Chambers on dorsal side long, narrow, separated by curved, strongly oblique sutures. Sutures raised and beaded. Only four or five chambers in last whorl. Marked wide umbilicus. Chambers on ventral side kidney-shaped, outlined by prominent ridges.

Remarks: The characteristic chamber arrangement of *Globotruncana fornicata* Plummer separates it clearly from other species with two well-developed keels. It is probably the ancestral form of *Globotruncana contusa* (Cushman), which is much more strongly convex dorsally and which always occurs in later strata.

Dimensions: Diameter 0.60 mm.; thickness 0.20 mm.

Occurrence: This species is known from the Brickhouse Bore, near Carnarvon, at depths between 715 feet and 1135 feet. It also occurs in the lower part of the Korojon calcarenite in the Giralia area. In Northwest Australia *Globotruncana fornicata* Plummer appears to have a wide geological range through Santonian and Campanian strata.

Globotruncana (Globotruncana) globigerinoides
Brotzen
Plate 2, figures 13–15

Globotruncana globigerinoides BROTZEN, 1936, Sver. Geol. Unders., ser. C, no. 396, p. 177, pl. 12, fig. 3a–c; pl. 13, fig. 3.
Rosalinella cf. *marginata* (Reuss). – MARIE, 1941, Paris, Mus. Nat. Hist. Nat., Mém., new ser., vol. 12, pp. 238–239, pl. 36, fig. 337a–c.
Rosalinella globigerinoides (Brotzen). – SCHIJFSMA, 1946, Netherlands, Geol. Stichting, Meded., ser. C, no. 7, p. 96, pl. 7, fig. 9a–c.
Globotruncana bulloides globigerinoides (Brotzen). – GANDOLFI, 1955, Bull. Amer. Pal., vol. 36, no. 155, p. 33, pl. 1, fig. 10.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Type no. 1987.

Description: Test lobate in outline, composed of globigerinoid chambers arranged in a low trochoid spire. Peripheral keel double, weakly developed. Carinal band equatorial or running obliquely across successive chambers. Chambers spherical, coiled in two or three whorls. Last whorl with four to six chambers. Ventral side with wide umbilicus, covered by umbilical plate in well-preserved specimens. Shell surface finely rugose.

Remarks: *Globotruncana globigerinoides* Brotzen appears more closely allied to *Globigerina*, especially *Rugoglobigerina*, than to other forms of *Globotruncana*. This has been pointed out by Brotzen (1942). The observed transition from such faintly carinate species to conspicuously keeled forms (see Hagn, 1953, p. 94) suggests the derivation of many bulloid forms of *Globotruncana* from Cretaceous forms of *Globigerina*.

Dimensions: Diameter 0.60 mm.; thickness 0.25 mm.

Occurrence: In Northwest Australia this species occurs in Campanian strata at depths between 455 feet and 855 feet in the Brickhouse Bore, near Carnarvon.

Globotruncana (Globotruncana) lapparenti Brotzen
subsp. lapparenti Brotzen
Plate 1, figures 7–9

Rosalina linnei d'Orbigny, type 1, DE LAPPARENT, 1918, Mém. Carte Géol. France, p. 7; p. 4, text-fig. 1a, c.
Globotruncana linnei (d'Orbigny). – RENZ, 1936 (part), Eclogae Geol. Helv., vol. 29, no. 1, pl. 6, figs. 32–34.
Globotruncana lapparenti BROTZEN, 1936, Sver. Geol. Unders., ser. C, no. 396, p. 175.
Globotruncana linnei typica VOGLER, 1941, Palaeontographica, Suppl.-Bd. 4, Abt. 4, Lief. 4, Abschnitt 4, p. 286, pl. 23, figs. 12–21.
Globotruncana linnei (d'Orbigny) Renz. – GANDOLFI, 1942, Riv. Ital. Pal., vol. 48, Mem. 4, pp. 125–130, pl. 3, fig. 3; pl. 4, figs. 18, 32–33; pl. 4, fig. 7.
Globotruncana lapparenti Brotzen subsp. *lapparenti* Brotzen. – BOLLI, 1945, Eclogae Geol. Helv., vol. 37, no. 2, p. 230, text-fig. 1 (15–16), pl. 9, fig. 11.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Type no. 1988.

Description: Test parallel-sided, compressed, flat on both dorsal and ventral sides. Dorsal sutures raised, beaded and oblique. Ventral chambers outlined by raised, over-lapping horseshoe-shaped ridges. Last whorl with four to six chambers. Double-keeled, with narrow, vertical carinal band. Marginal keels prominent and granular or beaded. Moderately wide ventral umbilicus.

Remarks: Brotzen (1936) proposed the name *Globotruncana lapparenti* to designate the forms which Lapparent (1918) had described under the name *Rosalina linnei* d'Orbigny with six varieties. The writer has based identi-fication of the Australian forms on the excellent figures given by Reichel (1950). Specimens figured by Hofker (1956) as *Globotruncana linneiformis* Hofker have more in-flated chambers, and it is doubtful whether this species is a true synonym of *Globotruncana lapparenti* Brotzen.

Dimensions: Diameter 0.45 mm.; thickness 0.15 mm.

Occurrence: This form occurs rarely in the Brickhouse Bore, Northwest Australia, at a depth of 995 feet. It has also been noted in the Gingin chalk and possibly in the lower part of the Korojon calcarenite. The geological range of this form in Western Australia appears to be Santonian to Campanian.

Globotruncana (Globotruncana) lapparenti Brotzen
cf. subsp. tricarinata (Quereau)
Plate 3, figures 1–3

Pulvinulina tricarinata QUEREAU, 1893, Beitr. Geol. Karte Schweiz, no. 33, pl. 5, fig. 3a.
Rosalina linnei d'Orbigny, type 2, DE LAPPARENT, 1918, Mém. Carte Géol. France, p. 7; p. 4, text-fig. 1b, d–f; p. 5, text-fig. 2d, n.

Globotruncana linnei (d'Orbigny). – RENZ, 1936 (part), Eclogae Geol. Helv., vol. 29, no. 1, p. 19, pl. 6, figs. 28–30; pl. 8, fig. 7.
Globotruncana linnei tricarinata (Quereau). – VOGLER, 1941, Palaeontographica, Suppl.-Bd. 4, Abt. 4, Lief. 4, Abschnitt 4, p. 287, pl. 33, figs. 22–31.
Globotruncana lapparenti tricarinata (Quereau). – BOLLI, 1945, Eclogae Geol. Helv., vol. 37, no. 2, pp. 232–233, text-fig. 1 (19–20); pl. 9, fig. 13.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Type no. 1989.

Description: Test shallowly biconvex, ventral side in-flated. There are two strong marginal keels separated by a vertical carinal band. An apparent third keel surrounds the umbilicus. Dorsal side shallowly convex with petaloid to arcuate chambers. Last whorl with six to seven chambers. Dorsal sutures raised and beaded. Ventral chambers prolonged around a wide umbilicus, which is covered by an umbilical plate in well-preserved specimens. Apertures periumbilical.

Remarks: The type description of this form is based entirely on thin sections (Quereau, 1893), and the sur-face characters have not been adequately described. The principal characteristic of the subspecies is the prolongation of the chambers on the ventral side to form a third, less prominent keel. Pending more complete knowledge of topotype material from the original locali-ties of Quereau, the Australian material is tentatively determined as *Globotruncana lapparenti* cf. subsp. *tricari-nata* (Quereau).

Dimensions: Diameter 0.55 mm.; maximum thickness 0.28 mm.

Occurrence: This ventrally inflated subspecies is found in the lower part of the Korojon calcarenite in the Car-narvon Basin, Northwest Australia. It occurs in strata that are correlated with the Campanian stage on the basis of microfossils.

Globotruncana (Globotruncana) lugeoni Tilev
Plate 2, figures 7–9

Globotruncana lugeoni TILEV, 1951, Maden Tetkik ve Arama Enstitüsü, Yayinlarindan, ser. B, no. 16, pp. 41–50; text-figs. 10a–c, 11: -d, 12a–e, 13a–d; pl. 1, figs. 5–7; pl. 2, fig. 1a–b; pl. 3, fig. 1.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Type no. 1990.

Description: Large, flat-topped *Globotruncana* with a single peripheral keel and a very deep base. Outline circular or very slightly lobate. Chambers on the dorsal side arcuate to angular, usually rather small. Last whorl with six to eight chambers. Dorsal sutures prominently raised and beaded, sharply reflexed at the periphery. Chambers on the ventral side are very prolonged, and in the later chambers their outer wall forms an angle of

90º with the dorsal surface. Umbilicus deep, covered by a small umbilical plate. Ventral sutures radial and slightly depressed. Ventral surface slightly pustulose.

Remarks: The numerous specimens examined from Northwest Australia are very similar to those described and figured from Turkey by Tilev (1951). Since *Globotruncana lugeoni* Tilev and its variety *Globotruncana lugeoni angulata* Tilev both occur in the same sample, it was thought unnecessary to consider the variety separately.

Species which closely resemble *Globotruncana lugeoni* Tilev are *Globotruncana gansseri* Bolli, 1951, and *Globotruncana elevata* (Brotzen). The latter has a distinct central boss on the dorsal side, and the chambers are less angular. Küpper (1956) has mentioned that *Globotruncana gansseri* Bolli has far fewer chambers in the last whorl and is more evolute than *Globotruncana lugeoni* Tilev.

Dimensions: Diameter 0.50 to 0.60 mm.; maximum height 0.35 mm.

Occurrence: This species occurs frequently in the Miria marl, where it is associated with Maestrichtian ammonites. It is less common in the Korojon calcarenite, which is considered to be of Campanian age. In Turkey and in Austria *Globotruncana lugeoni* Tilev is recorded only from Maestrichtian strata, but in Northwest Australia it occurs in both Maestrichtian and Campanian equivalents.

Globotruncana (Globotruncana) marginata (Reuss)
Plate 2, figures 4–6

Rosalina marginata REUSS, 1845, Verstein. Böhm. Kreide, pt. 1, p. 36, pl. 8, figs. 54, 74; pl. 13, fig. 68. – REUSS, 1854, Denkschr. K. Akad. Wiss. Wien, Math.-Naturw. Cl., vol. 7, p. 59, pl. 26, fig. 1.
Globigerina marginata (Reuss). – FRANKE, 1928, Abh. Preuss. Geol. Landesanst., new ser., no. 111, p. 192, pl. 18, fig. 9 a–c.
Globotruncana linnei bulloides VOGLER, 1941, Paleontographica, Suppl.-Bd. 4, Abt. 4, Lief. 4, Abschnitt 4, p. 287, pl. 23, figs. 32–39.
Globotruncana lapparenti bulloides Vogler. – BOLLI, 1945, Eclogae Geol. Helv., vol. 37, no. 2, pp. 231–232, text-fig. 1 (17–18); pl. 19, fig. 12.
Rosalinella marginata (Reuss). – SCHIJFSMA, 1946, Netherlands, Geol. Stichting, Meded., ser. C, no. 7, p. 97, pl. 7, fig. 10 a–c.
Globotruncana marginata (Reuss). – CUSHMAN, 1946, U.S. Geol. Survey, Prof. Paper no. 206, p. 150, pl. 62, figs. 1–2.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Type no. 1991.

Description: Shell lobate in outline, shallowly biconvex. Chambers inflated or bulloid. Dorsal sutures short and depressed. Last whorl with five to six chambers. Periphery strongly lobed, with two thin marginal keels separated by a narrow carinal band. Sutures on the ventral side radial and depressed. Umblicus small and covered by an umbilical plate with small apertures.

Remarks: In the original definition of this species by Reuss (1845), there was inadequate description and illustration. Recently, Hagn (1953) has given a detailed discussion and refiguring of *Globotruncana marginata* (Reuss). A similar form, described only from thin sections by Vogler (1941) and later by Bolli (1945) under the name *Globotruncana lapparenti bulloides* Vogler, appears to be a synonym of the much earlier species *Globotruncana marginata* (Reuss). More recently, Hofker (1956) has indicated that Reuss' description refers to a single-keeled form with inflated chambers. The interpretation of Hagn (1953) is followed in this paper.

Dimensions: Diameter 0.45 mm.; thickness 0.20 mm.

Occurrence: Within the Carnarvon Basin, Northwest Australia, *Globotruncana marginata* (Reuss) appears to be restricted to beds of Santonian and Campanian age. It has been noted from the Brickhouse Bore, near Carnarvon, at depths between 615 feet and 855 feet, and is relatively common in this interval. The Gingin chalk in the Perth Basin also yields typical specimens of Santonian age. In the Giralia area this species occurs in the lower part of the Korojon calcarenite.

Globotruncana (Globotruncana) paraventricosa (Hofker)
Plate 1, figures 1–3

Globigerina marginata (Reuss). – HERON-ALLEN AND EARLAND, 1910, Jour. Roy. Micr. Soc. London, p. 424, pl. 9, figs. 1–3.
Globotruncana ventricosa White. – BROTZEN, 1936, Sver. Geol. Unders., ser. C, no. 396, p. 171, pl. 13, fig. 4a–c; text-fig. 63.
Marginotruncana paraventricosa HOFKER, 1956, Neues Jahrb. Geol. Pal., Abh., vol. 103, no. 3, p. 328, text-figs. 17–18.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Type no. 1992.

Description: Shell slightly lobate in outline. Dorsal side flat or slightly convex. Ventral side moderately convex, with a large umbilical depression. Chambers on the dorsal side inflated, separated by strongly rounded sutures. Last whorl with six to eight petaloid chambers. Periphery with double marginal keels separated by a moderately wide, almost vertical carinal band. Chambers on the ventral side inflated and separated by short radial to oblique sutures.

Remarks: This species is characterized by the inflated nature of the chambers, both on the dorsal and ventral sides. It differs from *Globotruncana ventricosa* White, which shows no inflation of the chambers on the dorsal side and which is much deeper ventrally.

Dimensions: Diameter 0.50–0.60 mm.; thickness 0.25 mm.

Occurrence: Globotruncana paraventricosa (Hofker) occurs in strata of Campanian age in Northwest Australia. It has been found in the Brickhouse Bore, near Carnarvon, at a depth of 435 feet, and also in the lower part of the Korojon calcarenite in the Giralia area.

Globotruncana (Globotruncana) planata Edgell, new species
Plate 4, figures 7–9

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection: holotype (pl. 4, figs. 7–9), no. 1993; paratypes, no. 1994–1995.

Description: Shell parallel-sided, compressed, and double-keeled with a relatively narrow subvertical carinal band. Dorsal side almost flat, with arcuate to petaloid chambers separated by faintly raised, curved dorsal sutures. Last whorl with four to six chambers. Marginal keels both prominent and beaded. Ventral side flat, with a narrow umbilicus. Sutures on the ventral side curved, flush with the surface, not raised or beaded.

Remarks: This species is distinguished from the group of *Globotruncana lapparenti* Brotzen by the absence of raised ventral sutures and by a narrower umbilicus. The subspecies of *Globotruncana lapparenti* Brotzen are all characterized by prominent horseshoe-shaped ridges which outline the chambers on the ventral side. In addition, this new species appears to be restricted to Maestrichtian strata and is younger than most forms of *Globotruncana lapparenti* Brotzen.

Dimensions: Diameter 0.30 to 0.40 mm.; thickness 0.10 mm.

Occurrence: In Northwest Australia this distinctive species has been found only in the Miria marl formation, where it is associated with ammonites of Maestrichtian age.

Globotruncana (Globotruncana) spinea Kikoine
Plate 2, figures 1–3

Globotruncana spinea KIKOINE, 1947, C. R. Somm. Soc. Géol. France, no. 1–2, p. 21.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Type no. 1996.

Description: Shallowly trochoid, nearly parallel-sided. Truncate, double-keeled margin extending into stout peripheral spines on each of the four or five chambers of the last whorl. Chambers on the dorsal side arcuate, separated by limbate, raised and beaded sutures. Two peripheral keels separated by an inclined carinal band. Upper or dorsal keel more pronounced and extended into broad, spinose projections from each chamber. Ventral peripheral keel slightly beaded; beading forms a horseshoe-shaped ridge around each chamber on the ventral side. Narrow umbilical depression.

Remarks: This double-keeled species differs from the only other spined form, *Globotruncana calcarata* Cushman, which possesses only a single marginal keel. As noted by Kikoine (1947), there is a close relationship with *Globotruncana arca* (Cushman); he writes: "C'est en quel-

que sorte un *Globotruncana arca* (Cushman) dont la carène inférieure est remplacée par autant de protubérances situées à l'extrémité."

Dimensions: Diameter 0.35 mm.; thickness 0.10 mm.

Occurrence: This species has been noted rarely in the Gingin chalk, a 70-foot-thick formation that outcrops in the Perth Basin, Western Australia. The age of this formation is Santonian as indicated by the crinoids *Marsupites* and *Uintacrinus*.

Family GLOBIGERINIDAE

Genus **Rugoglobigerina** Bronnimann, 1952

Test shallowly to strongly trochoid, perforate, with a conspicuously rugose surface. Chamber arrangement *Globigerina*-like, may also be *Hantkenina*-like. Chambers inflated subglobular, separated by radial, depressed sutures. Umbilicus usually wide, deep, and subcircular with a covering plate. Arched umbilical apertures around margin of umbilical plate. Surface rugosities irregular or arranged in rows radially or equatorially.

Rugoglobigerina rugosa (Plummer)
Plate 4, figures 10–12

Globigerina rugosa PLUMMER, 1927, Univ. Texas Bull. no. 2644, p. 38, pl. 2, fig. 10a–d.
Rugoglobigerina (Rugoglobigerina) rugosa (Plummer). – BRONNIMANN, 1952, Bull. Amer. Pal., vol. 34, no. 140, pp. 34–35, pl. 4, figs. 1–3, 7–9.
Globotruncana (Rugoglobigerina) rugosa rugosa (Plummer). – GANDOLFI, 1955, Bull. Amer. Pal., vol. 36, no. 155, p. 72, pl. 7, fig. 6a–c; text-fig. 11c.

Repository: Bureau of Mineral Resources, Canberra, Australia; Commonwealth Palaeontological Collection, Type no. 1997.

Description: Shell large, composed of subglobular chambers coiled trochoidally. Dorsal side more or less strongly convex. Ventral side with a relatively wide umbilicus covered by an umbilical plate with marginal apertures. Chambers arranged in three whorls, with five to eight chambers in the final whorl. Shell surface ornamented by numerous coarse pustules or rugae which may unite to form short submeridional ridges. Ornamentation commonly irregular.

Remarks: The high-spired, compactly coiled, subglobular shape of the specimen figured in plate 4, figures 10–12, resembles the subspecies *Rugoglobigerina (Rugoglobigerina) rugosa rotundata* Bronnimann, described from the Maestrichtian of Trinidad. Abundant specimens of this species in the Upper Cretaceous of Northwest Australia indicate a wide range of variation, which makes detailed trinomial taxonomic subdivision meaningless.

Rugoglobigerina rugosa (Plummer) is closely related to members of the genus *Globotruncana*, and has in fact been regarded as representing a subgenus of the latter by

TABLE 1

STRUCTURAL CHARACTERISTICS OF GLOBOTRUNCANA FORMS FROM NORTHWEST AUSTRALIA

SPECIES OR SUBSPECIES	OUTLINE OF TEST	PROFILE OR CROSS-SECTION	PERIPHERAL KEELS OR CARINAE	CARINAL BAND	COILING	DORSAL SUTURES	VENTRAL SUTURES	DORSAL CHAMBER SHAPE	UMBILICUS	APERTURES	SURFACE CHARACTERS	DIMENSIONS
Glt. (Rotalipora) cf. turonica	moderately lobate	shallowly biconvex	single-keeled	none	shallow trochoid; 6 chambers in last whorl	depressed	depressed and radial	inflated and poly-hedral	wide and shallow	sutural and interio-marginal	smooth to slightly rugose	diam. 0.4 mm.
Glt. (Glt.) arca	subcircular	unequally biconvex	strongly bicarinate	inclined and narrow	moderately trochoid; 6 to 8 chambers in last whorl	curved, raised and beaded	oblique to radial; often raised	petaloid to arcuate	wide, with umbilical plate	umbilical	slightly beaded	diam. 0.5 mm. ht. 0.2 mm.
Glt. (Glt.) citae	lobate	concavo-convex	weakly unicari-nate	none	very shallowly trochoid; 4 to 5 chambers in last whorl	depressed, radial	depressed, radial	globige-rinoid, com-pressed	none	interio-marginal	hispid	diam. 0.37 mm. ht. 0.10 mm.
Glt. (Glt.) contusa	moderately lobate	very convex dorsally; flat ventrally	bicarinate	very narrow and inclined	strongly trochoid; about 6 chambers in last whorl	raised, beaded and tangential	curved and raised	narrow and elongate	wide, with umbilical plate	umbilical	beaded, especially on sutures	diam. 0.5 mm. ht. 0.4 mm.
Glt. (Glt.) elevata elevata	slightly lobate	plano-convex, central dorsal boss	strongly unicari-nate	none	shallowly trochoid; 6 to 8 chambers in last whorl	curved, raised and beaded	oblique to radial; often raised	petaloid; in a rosette pattern	moder-ately wide and deep	umbilical	slightly beaded, especially on sutures	diam. 0.4 to 0.6 mm. ht. 0.25 mm.
Glt. (Glt.) fornicata	subcircular	shallowly biconvex	bicarinate	narrow and slightly inclined	shallowly trochoid; 4 to 5 chambers in last whorl	raised, beaded, strongly oblique	curved and raised; reniform ventral chambers	narrow and elongate	very wide	umbilical	smooth except for raised sutures	diam. 0.6 mm. ht. 0.20 mm.
Glt. (Glt.) globigerinoides	strongly lobate	rounded biconvex	weakly bicarinate	narrow and sub-vertical	shallowly trochoid; 4 to 6 chambers in last whorl	short, radial and depressed	short, radial and depressed	inflated, globige-rinoid	wide, with umbilical plate	umbilical	finely rugose	diam. 0.60 mm. ht. 0.25 mm.
Glt. (Glt.) lapparenti lapparenti	subcircular	flat, paral-lel-sided, and com-pressed	strongly bicarinate	narrow and vertical	shallowly trochoid; 5 to 6 chambers in last whorl	highly raised, beaded and oblique	sigmoidal; overlap on each later chamber	arcuate and depressed	moder-ately wide, with umbilical plate	umbilical	beaded only on sutures and carinae	diam. 0.45 mm. ht. 0.15 mm.

TABLE 1 (*continued*)

STRUCTURAL CHARACTERISTICS OF GLOBOTRUNCANA FORMS FROM NORTHWEST AUSTRALIA

SPECIES OR SUBSPECIES	OUTLINE OF TEST	PROFILE OR CROSS-SECTION	PERIPHERAL KEELS OR CARINAE	CARINAL BAND	COILING	DORSAL SUTURES	VENTRAL SUTURES	DORSAL CHAMBER SHAPE	UMBILICUS	APERTURES	SURFACE CHARACTERS	DIMENSIONS
Glt. (Glt.) lapparenti cf. subsp. *tricarinata*	subcircular	shallowly biconvex	two prominent marginal keels and a third umbilical keel	vertical and moderately wide	moderately trochoid; 6 to 7 chambers in last whorl	raised, curved and beaded	sigmoidal to curved	petaloid to arcuate	wide, with umbilical plate	umbilical	beaded only on sutures and carinae	diam. 0.55 mm. ht. 0.28 mm.
Glt. (Glt.) lugeoni	circular	plano-convex	strongly unicarinate	none	moderately trochoid; 6 to 8 chambers in last whorl	raised, beaded and sharply reflexed at periphery	radial and slightly depressed	arcuate to angular	moderately wide and deep, with umbilical plate	umbilical	pustulose to rugose on ventral surface	diam. 0.55 mm. ht. 0.35 mm.
Glt. (Glt.) marginata	moderately lobate	shallowly biconvex	bicarinate	narrow and subvertical	shallowly trochoid; 5 to 6 chambers in last whorl	short, slightly curved and depressed	radial and depressed	inflated and globigerinoid	small, with umbilical plate	umbilical	smooth	diam. 0.45 mm. ht. 0.20 mm.
Glt. (Glt.) paraventricosa	slightly lobate	shallowly biconvex	strongly bicarinate	moderately wide and subvertical	shallowly trochoid; 6 to 8 chambers in last whorl	curved and slightly raised	radial and depressed	petaloid and slightly inflated	wide, with umbilical plate	umbilical	smooth	diam. 0.55 mm. ht. 0.25 mm.
Glt. (Glt.) planata	subcircular	flat, parallel-sided, and compressed	bicarinate	narrow and subvertical	shallowly trochoid; 4 to 6 chambers in last whorl	slightly curved, oblique and faintly raised	curved, not raised or beaded	arcuate	narrow and slightly depressed	umbilical	smooth except for beaded keels and sutures	diam. 0.35 mm. ht. 0.10 mm.
Glt. (Glt.) spinea	spinose	flat, parallel-sided	strongly bicarinate with stout spines	inclined and narrow	shallowly trochoid; 4 to 5 chambers in last whorl	slightly curved, raised and beaded	curved, raised and beaded	arcuate	relatively narrow	umbilical	smooth except for beaded keels and sutures	diam. 0.35 mm. ht. 0.10 mm.

Gandolfi (1955). This subgeneric grouping is not possible, as *Rugoglobigerina* does not possess the peripheral keel characteristic of *Globotruncana*. The morphology of *Rugoglobigerina* is, however, very similar to the more globigerinoid forms of *Globotruncana*, such as *Globotruncana globigerinoides* Brotzen. Also, the rugose surface and conspicuous umbilical plate are common to both *Globotruncana* and *Rugoglobigerina*.

Dimensions: Diameter 0.30 to 0.40 mm.

Occurrence: This species occurs commonly in the Brickhouse Bore at depths between 350 feet and 635 feet. It also occurs abundantly in the Korojon calcarenite and Miria marl in the Giralia Anticline. The geological range of *Rugoglobigerina rugosa* (Plummer) in Northwest Australia appears to be Campanian and Maestrichtian.

STRUCTURAL CHARACTERISTICS OF GLOBOTRUNCANA

The principal morphological features which are of value in discriminating the species and subspecies of *Globotruncana* are as follows:

1) *Peripheral keels or carinae:* Whether double-keeled or single-keeled; whether weakly or prominently keeled.

2) *Carinal band:* Whether inclined or vertical; whether wide or narrow.

3) *Profile:* Whether biconvex or planoconvex, inflated or compressed in side view.

4) *Outline:* Whether lobate, spinose, or circular in plan view.

5) *Chamber shape on dorsal side:* Whether petaloid, polyhedral, arcuate, elongate, or bulloid.

6) *Dorsal sutures:* Whether oblique, curved or radial; whether depressed or raised; if raised, whether continuous or beaded.

7) *Ventral sutures:* Whether radial, tangential or sigmoidal; whether raised or depressed.

8) *Coiling:* Whether evolute or involute; degree of size increase in successive chambers and number of chambers in last whorl.

9) *Umbilicus:* Whether wide or narrow; with or without umbilical plate.

10) *Apertures:* Whether sutural, interiomarginal or umbilical.

11) *Surface characters:* Whether smooth, rugose, beaded or hispid; size and distribution of pores.

Those species and subspecies of *Globotruncana* noted by the writer in Northwest Australia have been identified on the basis of the structural features listed above. Table 1 summarizes the diagnostic features of each of these forms of *Globotruncana*.

MORPHOGENETIC TRENDS IN GLOBOTRUNCANA FROM NORTH-WEST AUSTRALIA

In the genus *Globotruncana* as a whole, the most obvious morphological change is from a single peripheral keel in the oldest forms, through double-keeled intermediate types, to ultimate single-keeled species in the uppermost Cretaceous. Another trend in the evolution of *Globotruncana* is the development of the umbilicus, with a covering umbilical plate. The early forms of the genus, such as *Rotalipora*, have only a shallow umbilicus, and the apertures are interiomarginal and sutural. These sutural apertures seem to contract toward the center in later species to form a wide umbilicus with umbilical apertures and a well-developed covering plate.

In order to consider the morphogenetic trends by which the species of *Globotruncana* have evolved, it is necessary to group together those forms which have close structural relationships. The forms of *Globotruncana* found in Northwest Australia can be divided into six morphological groups, as follows:

1) Group of *Globotruncana (Rotalipora)* cf. *turonica* (Brotzen): Primitive single-keeled species with sutural apertures.

2) Group of *Globotruncana lapparenti* Brotzen: Strongly double-keeled and flat-sided forms with a vertical carinal band. This group includes *Globotruncana lapparenti lapparenti* Brotzen, *Globotruncana lapparenti tricarinata* (Quereau), and *Globotruncana spinea* Kikoine.

3) Group of *Globotruncana fornicata* Plummer and *Globotruncana contusa* (Cushman): Double-keeled forms of variable dorsal convexity with an inclined carinal band and with arcuate or elongate chambers. *Globotruncana arca* (Cushman) may also belong to this group.

4) Group of *Globotruncana globigerinoides* Brotzen, *Globotruncana marginata* (Reuss), and *Globotruncana paraventricosa* (Hofker): Double-keeled species with inflated globigerinoid chambers.

5) Group of *Globotruncana elevata* (Brotzen) and *Globotruncana lugeoni* Tilev: Specialized single-keeled forms of the late Cretaceous, with a strongly inflated ventral side.

6) Group of *Globotruncana citae* Bolli: Distinctly compressed, faintly single-keeled forms with no umbilical plate.

There appears to be a phyletic line starting from Cenomanian-Turonian single-keeled *Rotalipora* types. By acquisition of a second keel, deflation of the chambers, and enlargement of the umbilicus, this line leads to forms such as *Globotruncana lapparenti lapparenti* in the Santonian and Campanian. In the Santonian a spinose development of the dorsal marginal keel of *Globotruncana lapparenti* is responsible for species such as *Globotruncana spinea*. By prolongation of the chambers on the ventral side, *Globotruncana lapparenti lapparenti* gives rise to *Globotruncana lapparenti tricarinata*, in which a third keel is developed around the umbilicus.

The double-keeled species *Globotruncana fornicata* may also have originated from the group of *Globotruncana lapparenti*. By increase in dorsal convexity, the Santonian-Campanian form *Globotruncana fornicata* gives rise to *Globotruncana contusa* in the Maestrichtian.

A separate phyletic line, starting from *Globigerina* or *Rugoglobigerina*, appears to give rise to the double-keeled forms of *Globotruncana* which have inflated globigerinoid chambers. In material from the Brickhouse Bore there is a gradation from non-keeled types of *Rugoglobigerina*, through forms with a very faint keel, to distinctly keeled types, which are considered to be *Globotruncana globigerinoides*. The latter species in turn gives rise to more strongly double-keeled species in which the chambers are still inflated and globigerinoid. Thus *Globotruncana marginata* and *Globotruncana paraventricosa* probably originated from *Globotruncana globigerinoides*.

The writer thus postulates two main lineages of double-keeled *Globotruncana*. Firstly, there is the *Globotruncana lapparenti* group, which developed from *Rotalipora*-like ancestors and which may have given rise to other species such as *Globotruncana arca*, *Globotruncana spinea*, *Globotruncana fornicata* and *Globotruncana contusa;* a second lineage of double-keeled forms with globigerinoid chambers consists of *Globotruncana globigerinoides*, *Globotruncana marginata* and *Globotruncana paraventricosa*, and may have originated from *Globigerina* or *Rugoglobigerina*.

CONCLUSIONS

A study of fourteen species and subspecies of *Globotruncana* from Upper Cretaceous strata in Northwest Australia provides a succession of stratigraphically restricted forms of value in local correlation. Most of these forms are widely distributed guide species of *Globotruncana* known from the Cretaceous of Europe and Central America. Species such as *Globotruncana contusa* (Cushman) and *Globotruncana citae* Bolli occur elsewhere only in strata of Maestrichtian age. The occurrence of these and other restricted species establishes a basis for age correlation with the standard stages of the European Upper Cretaceous. Correlation on the basis of *Globotruncana* indicates that the Cretaceous strata in the northern part of the Carnarvon Basin of Northwest Australia are equivalent in part to the Cenomanian-Turonian, Santonian, Campanian and Maestrichtian stages.

From the frequency distribution of *Globotruncana* in a succession of samples it appears that the adult forms of this genus were benthonic. The numerical abundance of *Globotruncana* is greatest where known benthonic genera are most abundant, and is least where definite planktonic forms are most numerous. The heavy, beaded, carinate shell of this genus, as well as the complex umbilical plate, is also suggestive of a benthonic habitat.

A summary of the structural characteristics that are of use in the definition of species and subspecies of *Globotruncana* is given in Table 1. The forms noted in Northwest Australia are divided into six morphological

groups, and the morphogenetic trends in these groups provide a tentative phylogeny for some of the Upper Cretaceous forms of *Globotruncana*.

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EXPLANATION OF PLATES

PLATE 1
All figures × ca. 73.

1–3   *Globotruncana (Globotruncana) paraventricosa* (Hofker)
Sample GE/56: Upper Cretaceous, Campanian, Korojon calcarenite, Giralia Range, Northwest Australia. 1, dorsal view; 2, side view; 3, ventral view. Hypotype no. 1992.

4–6   *Globotruncana (Globotruncana)* cf. *lapparenti* Brotzen
Sample GC/307: Upper Cretaceous, Campanian, Korojon calcarenite, Giralia Range, Northwest Australia. 4, dorsal view; 5, side view; 6, ventral view. Hypotype no. 1998.

7–9   *Globotruncana (Globotruncana) lapparenti* Brotzen subsp. *lapparenti* Brotzen
Upper Cretaceous, Campanian, Brickhouse Bore, depth 995 feet, Northwest Australia. 7, dorsal view; 8, side view; 9, ventral view. Hypotype no. 1988.

10–12   *Globotruncana (Globotruncana) arca* (Cushman)
Sample GC/307: Upper Cretaceous, Campanian, Korojon calcarenite, Giralia Range, Northwest Australia. 10, dorsal view; 11, side view; 12, ventral view. Hypotype no. 1980.

13–15   *Globotruncana (Globotruncana) citae* Bolli
Sample GE/29: Upper Cretaceous, Maestrichtian, Miria marl, Giralia Range, Northwest Australia. 13, dorsal view; 14, side view; 15, ventral view. Hypotype no. 1981.

16–18   *Globotruncana (Rotalipora)* cf. *turonica* (Brotzen)
Upper Cretaceous, Cenomanian—Turonian, Brickhouse Bore, depth 1210 feet, Northwest Australia. 16, dorsal view; 17, side view; 18, ventral view. Hypotype no. 1978.

PLATE 2

1–3   *Globotruncana (Globotruncana) spinea* Kikoine
Upper Cretaceous, Santonian, Gingin chalk, Western Australia. 1, dorsal view; 2, side view; 3, ventral view; all × ca. 73. Hypotype no. 1996.

4–6   *Globotruncana (Globotruncana) marginata* (Reuss)
Sample GC/308: Upper Cretaceous, Campanian, Korojon calcarenite, Giralia Range, Northwest Australia. 4, dorsal view; 5, side view; 6, ventral view; all × ca. 73. Hypotype no. 1991.

7–9   *Globotruncana (Globotruncana) lugeoni* Tilev
Sample GC/301: Upper Cretaceous, Maestrichtian, Miria marl, Giralia Range, Northwest Australia. 7, dorsal view; 8, side view; 9, ventral view; all × 54. Hypotype no. 1990.

10–12   *Globotruncana (Globotruncana) contusa* (Cushman)
Sample GE/30: Upper Cretaceous, Maestrichtian, Miria marl, north end of Giralia Anticline, Northwest Australia. 10, dorsal view; 11, side view; 12, ventral view; all × ca. 56. Hypotype no. 1982.

13–15   *Globotruncana (Globotruncana) globigerinoides* Brotzen
Upper Cretaceous, Campanian, Brickhouse Bore, depth 655 feet, Northwest Australia. 13, dorsal view; 14, side view; 15, ventral view; all × ca. 56. Hypotype no. 1987.

PLATE 3
All figures × ca. 73.

1–3   *Globotruncana (Globotruncana) lapparenti* Brotzen cf. subsp. *tricarinata* (Quereau)
Sample GE/21: Upper Cretaceous, Campanian, Korojon calcarenite, north end of Giralia Anticline, Northwest Australia. 1, dorsal view; 2, side view; 3, ventral view. Hypotype no. 1989.

4–6   *Globotruncana (Globotruncana) arca* (Cushman)
Sample GC/307: Upper Cretaceous, Campanian, Korojon calcarenite, Giralia Range, Northwest Australia. 4, dorsal view; 5, side view; 6, ventral view. Hypotype no. 1980.

7–9   *Globotruncana (Globotruncana) cf. contusa* (Cushman)
Sample GC/301: Upper Cretaceous, Maestrichtian, Miria marl, Giralia Range, Northwest Australia. 7, dorsal view; 8, side view; 9, ventral view. Hypotype no. 1983.

10–12   *Globotruncana (Globotruncana) fornicata* Plummer
Sample GC/308: Upper Cretaceous, Campanian, Korojon calcarenite, Giralia Range, Northwest Australia. 10, dorsal view; 11, side view; 12, ventral view. Hypotype no. 1986.

13–15   *Globotruncana (Globotruncana) arca* (Cushman)
Sample GC/307: Upper Cretaceous, Campanian, Korojon calcarenite, Giralia Range, Northwest Australia. 13, dorsal view; 14, side view; 15, ventral view. Hypotype no. 1999.

PLATE 4

1–3   *Globotruncana (Globotruncana) contusa* (Cushman)
Sample GE/30: Upper Cretaceous, Maestrichtian, Miria marl, north end of Giralia Anticline, Northwest Australia. 1, dorsal view; 2, side view; 3, ventral view; all × ca. 74. Hypotype no. 1984.

4–6   *Globotruncana (Globotruncana) elevata elevata* (Brotzen)
Sample GE/27: Upper Cretaceous, Maestrichtian, Miria marl, north end of Giralia Anticline, Northwest Australia. 4, dorsal view; 5, side view; 6, ventral view; all × ca. 74. Hypotype no. 1985.

7–9   *Globotruncana (Globotruncana) planata* Edgell, n. sp.
Sample GE/28: Upper Cretaceous, Maestrichtian, Miria marl, north end of Giralia Anticline, Northwest Australia. 7, dorsal view; 8, side view; 9, ventral view; all × 128. Holotype, no. 1993.

10–12   *Rugoglobigerina rugosa* (Plummer)
Sample GC/301: Upper Cretaceous, Maestrichtian, Miria marl, Giralia Range, Northwest Australia. 10, dorsal view; 11, side view; 12, ventral view; all × ca. 90. Hypotype no. 1997.
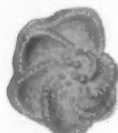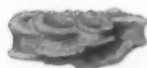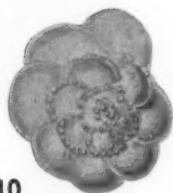
PLATE 3
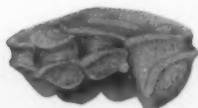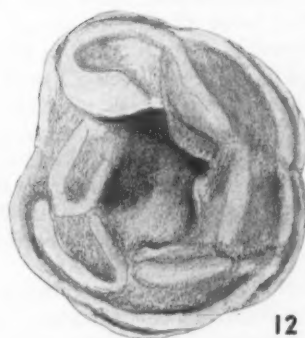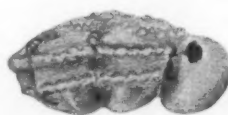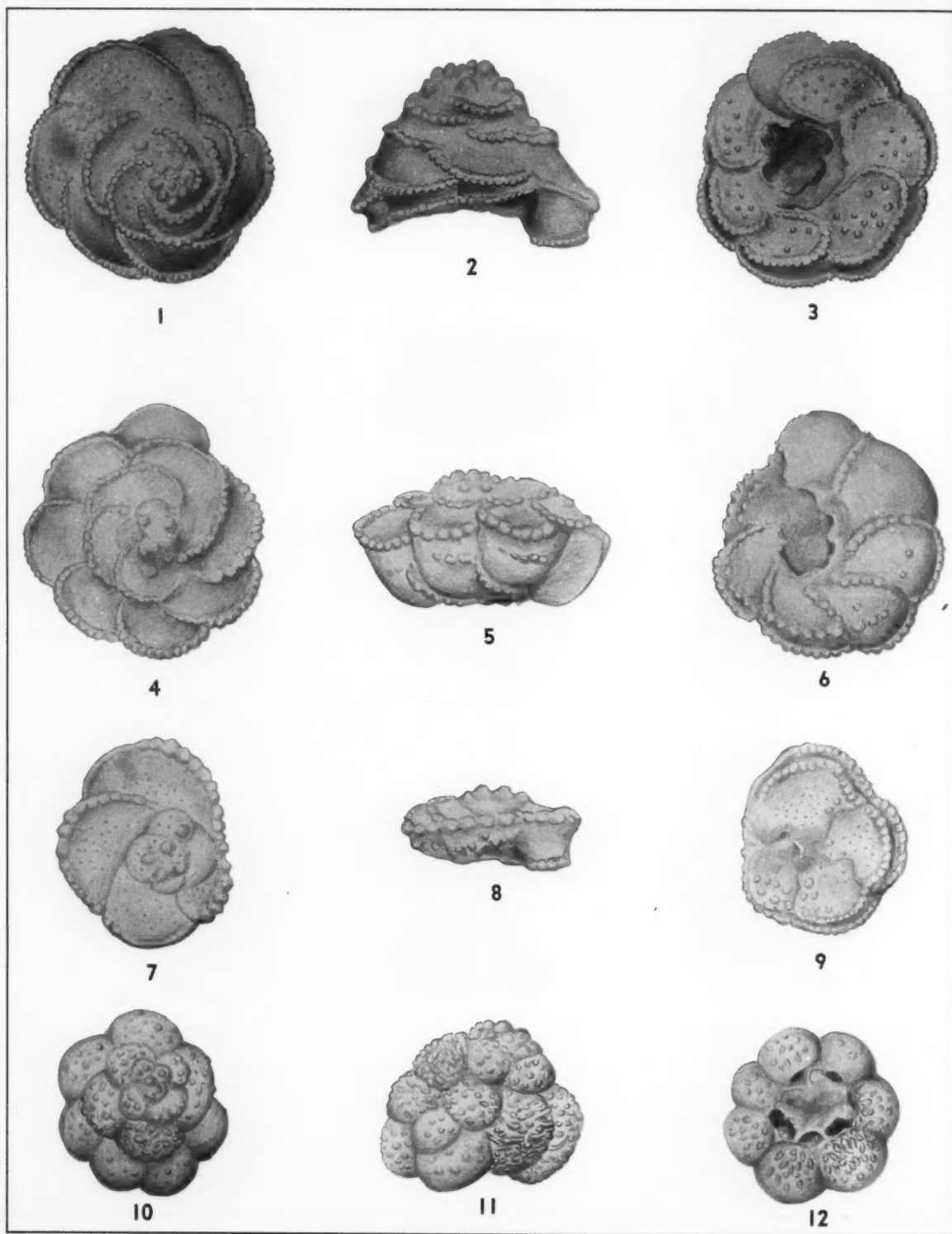
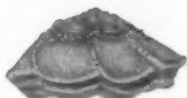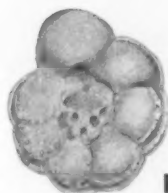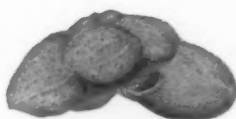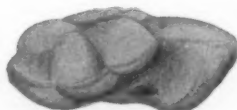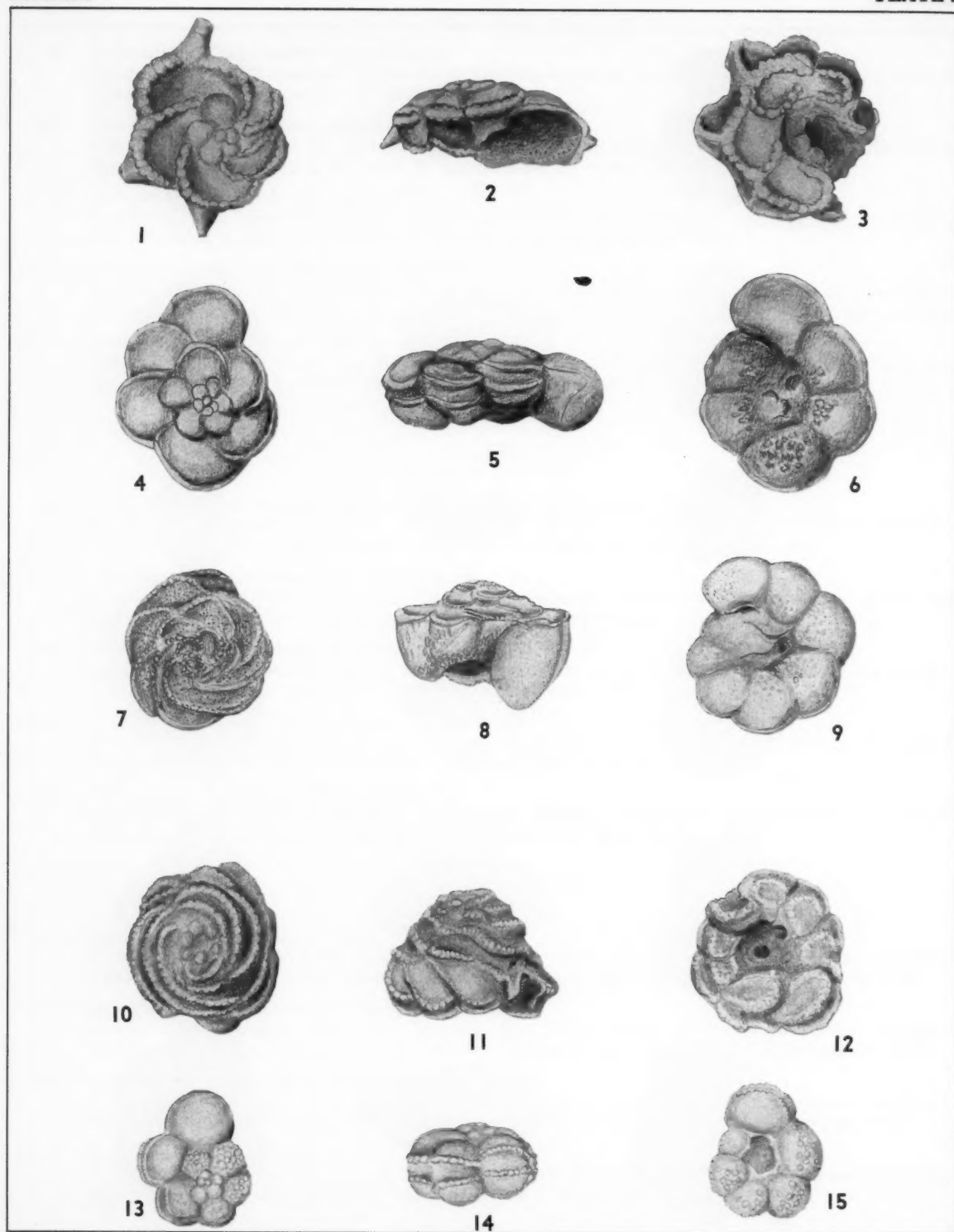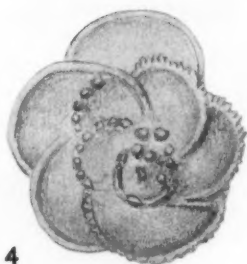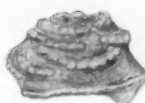ABSTRACT: *Silicoflagellates from twenty samples of the Calvert formation (Miocene) of Maryland were investigated morphologically, taxonomically, and stratigraphically. A brief history of the group, and the classification of fossil forms following Deflandre are included. Three genera with six species and seven varieties, six of which may prove to be new with further investigation, are described. A redefinition of existing species and an investigation of various sedimentary rock types containing these fossils are necessary before the true stratigraphic value of the silicoflagellates can be determined.*

Silicoflagellates of the Calvert formation (Miocene) of Maryland

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INTRODUCTION

The silicoflagellates of the Calvert formation (Miocene) of Maryland were studied both from the point of view of comparative morphology and in order to evaluate their possible stratigraphic usefulness. Examination of diatomaceous earth from the Calvert formation of Maryland revealed the presence of silicoflagellates in numbers great enough to permit a study of this type. Randle Cliff Beach, Calvert County, Maryland, was selected for sampling, as a typical section of the Calvert formation is there exposed and easily accessible for study.

Sincere appreciation is expressed to Dr. L. R. Wilson for defining the problem and for helpful suggestions during the course of the study, and to Thomson King, Thomas Rice, and Robert Hulsman for their assistance with the field work.

STRATIGRAPHY

The Miocene deposits of the Middle Atlantic slope have been described under the name of the Chesapeake group (Darton, 1891). The Chesapeake group in Maryland is composed of the Calvert, Choptank, and St. Marys formations.

The Calvert formation (Shattuck, 1902) lies at the base of the Chesapeake group in Maryland and takes its name from Calvert County, where it is typically developed and exposed for nearly thirty miles in the Calvert Cliffs along the eastern border of Calvert County from Chesapeake Beach to Drum Point. The formation outcrops in a band eighteen to twenty-four miles wide from the Delaware state boundary to the Potomac River. In other parts of Maryland it is found in the subsurface of the southeastern corner of Kent County, almost all of Queen Annes, and the northern portions of Talbot and Caroline Counties, in the area known locally as the Eastern Shore. On the Western Shore, the Calvert formation is found extensively developed in the subsurface of Anne Arundel, Prince Georges, Charles, Calvert, and St. Marys Counties.

Shattuck (1904) subdivided the Calvert formation into sixteen zones based on the paleontology and lithology. The basal member of the Calvert formation is the Fairhaven diatomaceous earth. It is characterized by a large number of diatoms in a very finely divided quartz matrix. The lower twenty feet of this member is very diatomaceous, being composed locally of as much as 50 per cent diatom frustules. The upper fifty feet is diatomaceous but too impure to be called diatomaceous earth. Shattuck further divided the Fairhaven member into three zones, which he called zones 1, 2, and 3, with zone number 1 being the oldest. Overlying the
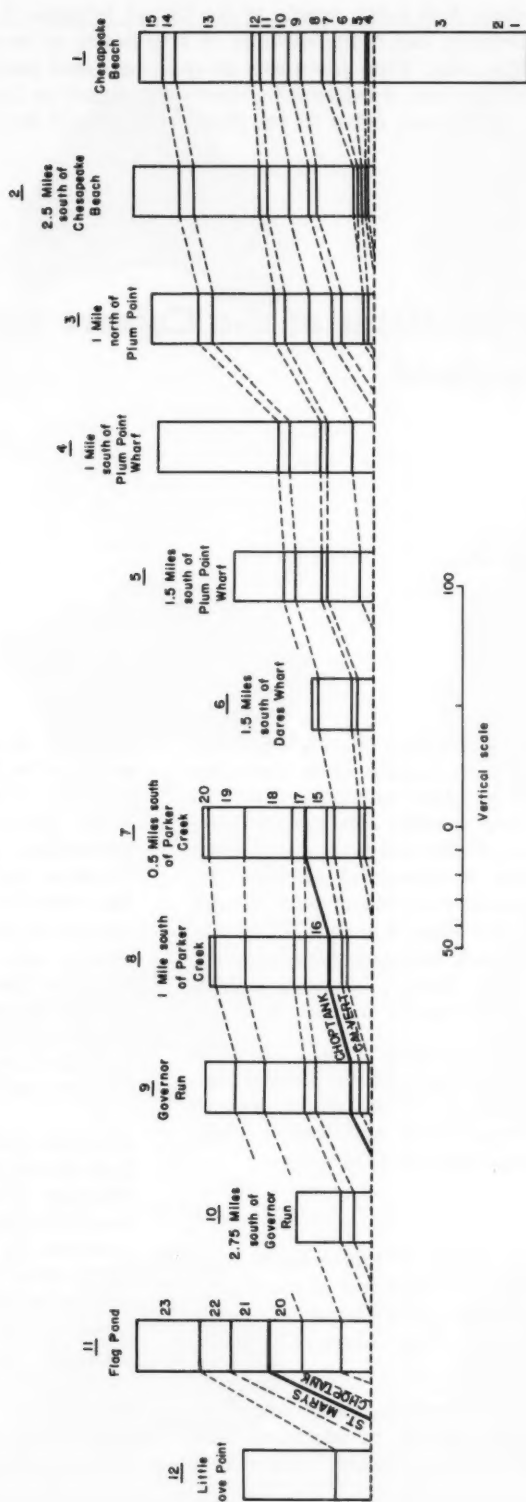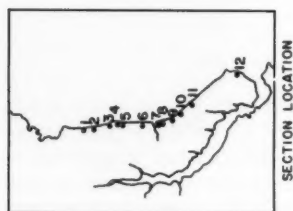
TEXT-FIGURE 1

Columnar sections of Miocene strata in the Calvert Cliffs of Maryland. Paleontologic zones are numbered in ascending order from 1 to 23. Zones of the Calvert formation are 1–15, of the Choptank formation 16–20, and of the St. Marys formation 21–23. Adopted from Shattuck (1904).

Fairhaven member is the Plum Point marl member, which is characterized by a series of sandy clays and marls. These beds include a great number of organic remains. This member is about eighty feet thick and has been subdivided into twelve zones by Shattuck.

The total thickness of the Calvert formation in Calvert County has not been definitely determined but is probably close to 150 feet. The Calvert formation is separated from the underlying Eocene Nanjemoy formation by an unconformity, but its relationship to the overlying Miocene Choptank formation has not been established. Text-figure 1 shows the relationships of the Miocene beds exposed in the Calvert Cliffs according to Shattuck's division of the Miocene in Maryland. These zones are illustrated here and have been carried in the literature as a matter of historical interest, but field observation of the zones is not certain in many instances.

Sampling was accomplished by first marking a vertical column on the exposure and removing the outer two to three inches of weathered sediments. The cleaned column was then divided into sample areas consisting of about one by three feet of surface area. Small portions of sediments were taken at intervals within the sample area so as to give a representative sample. A total of twenty samples was collected in a section 39 feet 10 inches in thickness. The section sampled includes the upper three feet of Shattuck's zone 3 of the Fairhaven diatomaceous earth member to approximately zone 10 of the Plum Point marl member. The Chesapeake Beach section in text-figure 1 shows the stratigraphic position of the sample area. The preparation of the samples for study followed the standard procedure for the preparation of radiolaria.

HISTORY

The first mention of silicoflagellates in the literature was in a paper by C. G. Ehrenberg (1840*a*), who described them from the Tertiary of Sicily. He considered the silicoflagellates to be diatoms. Müller (1855) transferred the silicoflagellates from the diatoms to the radiolarians, and Haeckel (1887) followed that practice in his "Report on the Radiolaria collected by H.M.S. *Challenger*." Borgert (1891) observed the flagella in living forms and defined the group Silicoflagellata. In 1901, Lemmermann monographed the group, listing all the species and literature known to him. The earliest descriptions known to the writer of silicoflagellates from the United States were of *Distephanus crux* (Ehrenberg) and *Dictyocha fibula* Ehrenberg from the Miocene of Mary-

land (Martin, 1904). In these descriptions the silicoflagellates were considered to be radiolarians. Hanna (1928) described as new the three genera *Corbisema*, *Lyramula*, and *Vallacerta* from the Moreno shale (Upper Cretaceous) of the Panoche Hills, Fresno County, California.

Until 1930, classification of the silicoflagellates was based on the number of sides in the basal body ring and the configuration of the apical structure (Gemeinhardt, 1930). In 1932, Deflandre, working with fossil material, and Hovasse, working with modern plankton populations, demonstrated that the differentiation of genera and species by the existing methods was inadequate. Deflandre (1936) attempted to assemble the information of various writers into a workable system of classification, which was to include living as well as fossil forms. This system proved valid for living forms but did not prove practical for fossil forms. In 1950 Deflandre established the system of classification of fossil silicoflagellates followed in this study. In this system Deflandre defines two families and one group incertae sedis. The family Dictyochidae includes the genera *Corbisema*, *Dictyocha*, *Paradictyocha*, *Mesocena*, *Naviculopsis*, *Phyllodictyocha*, and *Nothyocha*. The family Vallacertidae includes the genera *Vallacerta*, *Cornua*, and *Lyramula*. The group incertae sedis includes forms associated with the silicoflagellates and possessing certain morphological characteristics in common with them, but not definitely related. The genera of this group are *Clathropyxidella*, *Clathrium*, and *Pseudorocella*.

BIOLOGY

The silicoflagellates are planktonic marine flagellates with a siliceous internal skeleton. Phylogenetically, the silicoflagellates constitute a small group related to the large order Chrysomonadina of the class Flagellata. The internal skeleton of the silicoflagellates is composed of opaline silica and is generally hollow. The skeleton consists of a basal body ring with radial spines originating at the angles of the three- to ten-sided basal body ring. An apical structure consisting of a bar, plate, or ring is connected to the basal body ring by a number of lateral rods which is equal to the number of sides in most cases. The apical structure may be simple or complex. Accessory spines may be present on any or all of the skeletal components. The skeleton is ornamented with pits and beads, which may be in a definite pattern. The ornamentation may be pronounced, reduced, or absent. The nomenclature of the skeleton is given in text-figure 2.
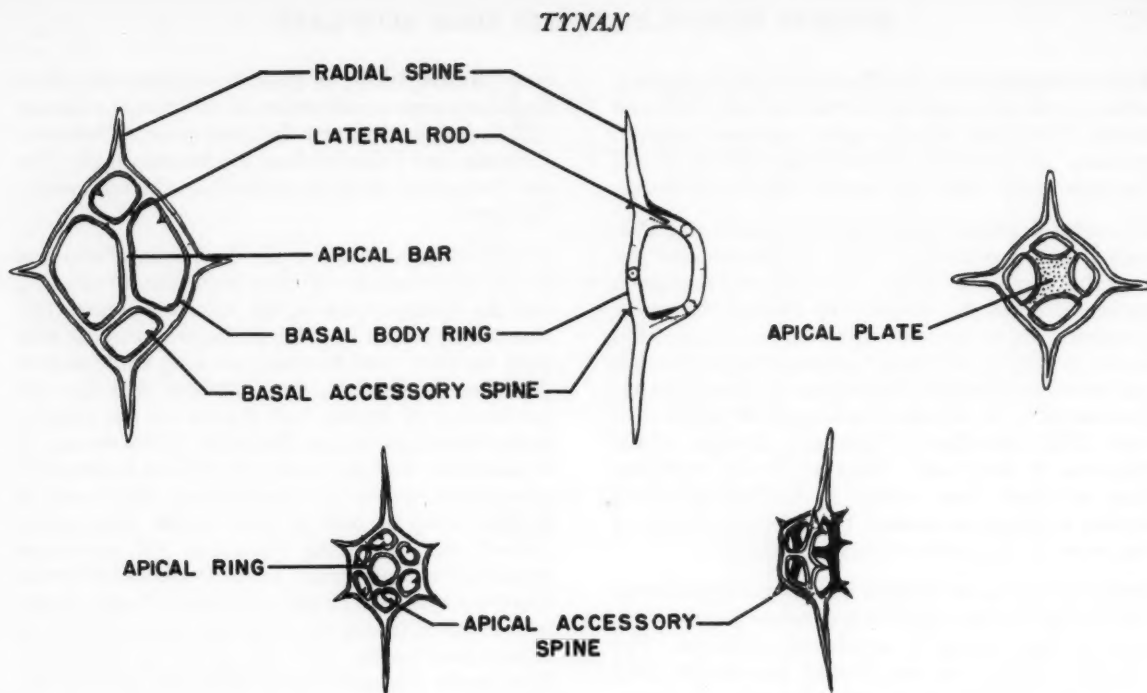
TEXT-FIGURE 2
NOMENCLATURE OF THE SILICOFLAGELLATE SKELETON

SYSTEMATIC DESCRIPTIONS

Family DICTYOCHIDAE Lemmermann, 1901

Genus CORBISEMA Hanna, 1928, emend. Frenguelli, 1940

Corbisema trigona (Zittel) Deflandre
Plate 1, figures 1–2

Dictyocha trigona ZITTEL, 1876, Deutsch. Geol. Ges., Zeitschr., vol. 28, p. 83, pl. 11, fig. 6a–b. – RÜST, 1888, Palaeontographica, vol. 34, p. 213.
Corbisema trigona (Zittel). – DEFLANDRE, 1950, Microscopie, vol. 2, pp. 51–52, text-fig. 130.

Basal body ring an equilateral triangle with short radial spines originating at the corners of the triangle, with sides slightly inflected in the center portion at the juncture with the lateral rods. The apical structure consists of a simple "Y" formed by the central joining of the lateral rods. Basal or apical accessory spines not present. There is no apical rod, plate, or ring. Length of the sides 20 microns. Length of the radial spines 8 microns. Apical structure arched slightly above the plane of the basal body ring.

Two specimens were observed in this study of over 1500 individuals. The description is in accord with that given by Deflandre (1950, p. 52, text-fig. 130) with the exception of the size. Deflandre gives 75 microns as the length of a side, whereas the two specimens found in this investigation both measure 20 microns. The length of the sides of these specimens corresponds closely with specimens definitely identified as *Dictyocha crux*.

These small forms have caused difficulty for considerable time. Schulz (1928) described similar small forms from the Cretaceous, which he assigned to *Dictyocha triacantha* var. *hastata* and *Dictyocha triacantha* var. *archangelskiana*. Schulz indicated the existence of very small forms of about 12 microns which he called *Dictyocha triacantha* var. *apiculata* Lemmermann form *minor* Schulz.

Deflandre (1950, p. 53) states that he believes that *Corbisema trigona* actually should be included in *Corbisema triacantha*, according to his revision of these small forms, but that a detailed investigation should be made before placing *Corbisema trigona* in synonymy with *Corbisema triacantha*.

One of the two specimens observed in this investigation (pl. 1, fig. 2) is here called *Corbisema trigona*, but there is considerable doubt as to the validity of the classification. The basal body ring is rectangular with a slight elongation of the major axis, with four radial spines in two pairs of unequal length originating at the corners of the rectangle, and with sides slightly inflected at the center at the juncture with the lateral rods. The apical structure is simple, consisting of four lateral rods merged at the center. The basal accessory spines are prominent and offset from the lateral rods. The length, not includ-

ing the radial spines, is 22 microns; spines on the same axis measure 12 microns. The width, not including the radial spines, is 18 microns; spines on the same axis measure 4 microns.

An examination of the two specimens described here as *Corbisema trigona* will show that similarities between the two are great. The simple apical structure characteristic of the genus *Corbisema* is present in both forms. Variations are present in the number of sides and in the presence or absence of basal accessory spines. Both *Corbisema* and *Dictyocha* may have either three or four sides. Both genera have basal accessory spines, which, in the case of *Corbisema*, are at the base of the lateral rods, whereas in *Dictyocha* they are offset from the lateral rods. The triangular form (pl. 1, fig. 1) has no basal accessory spines, but many individuals of both genera have been observed without basal accessory spines. The rectangular form (pl. 1, fig. 2) has the basal accessory spines offset in the manner of *Dictyocha*. The dimensions of the sides of both specimens of *Corbisema trigona* are in close agreement with individuals of the genus *Dictyocha*. The two forms exhibit characteristics of both *Corbisema* and *Dictyocha*. The limited numbers of these forms in the samples studied make a detailed study of types impractical.

Genus DICTYOCHA Ehrenberg, 1839

Dictyocha crux Ehrenberg
Plate 1, figures 3–8

Dictyocha crux EHRENBERG, 1840, K. Preuss. Akad. Wiss. Berlin, Ber., p. 207; 1854, Mikrogeologie, pl. 18, fig. 56; pl. 20, fig. 46a–c; pl. 23, no. 15, fig. 9.
Distephanus crux (Ehrenberg). – HAECKEL, 1887, Rept. Voy. Challenger, Zool., vol. 18, pt. 2, p. 1563. – MARTIN, 1904, Maryland, Geol. Survey, Miocene, p. 448, pl. 130, figs. 1–2. – DEFLANDRE, 1932, Soc. Bot. France, Bull., vol. 79, p. 495, text-figs. 1–6; p. 502, text-figs. 36–39; 1932, Soc. Franç. Microsc., Bull., vol. 1, p. 19, text-figs. 41–44.

Basal body ring of four equidimensional sides, which may be straight or inflated, with four radial spines which may be equal in length or in two pairs of unequal length, with or without basal accessory spines. Apical structure composed of four lateral rods connecting a four-sided apical ring to the basal body ring. Surface ornamentation present or absent.

The genus *Distephanus* Haeckel, 1887 (Deflandre, 1932*a*, p. 14) includes all forms with skeletons composed of polygonal basal body and apical rings. The genus *Dictyocha* Ehrenberg, 1839 (Deflandre, 1950, p. 47) includes forms which may have a variable number of sides (three, four to nine, or ten) and an apical structure that is simple or complex, with one or more apical apertures. Forms with essentially the same basal body ring configuration but with variation of the apical structure would fall into two genera, according to Haeckel's classification. If the apical structure were simple, the form would be assigned to *Distephanus*; if complex to *Cannopilus*. The configuration of the basal

body ring is identically duplicated in reproduction, but there is considerable variation in the apical structure. It follows that forms of similar basal body ring configuration should be considered more closely related than those of similar apical structure. Deflandre (1950) has redefined the genus *Cannopilus*, and distephanoid forms cannot be included. According to Deflandre (1950), forms formerly known as *Distephanus* and also a few known as *Cannopilus* should now be assigned to the genus *Dictyocha*.

Dictyocha crux is the dominant species throughout the section studied. The average percentage composition of the silicoflagellate population of each sample was approximately 90 per cent *Dictyocha crux*.

Investigations may show that this species should be further divided into at least two varieties or subspecies, for there are two size classes. The smaller size class averages approximately 24 microns in length and width. The larger of the two classes is generally not equidimensional, one axis being slightly greater. The length of this class averages approximately 32 microns, and the width approximately 30 microns. The smaller size class is illustrated in figures 3–5 on plate 1, and the larger size class by figures 6–8. There is intergradation between the two size classes, but this may be a reflection of the orientation of the specimen in the mounting medium. When the specimen is not in a perfectly horizontal plane, the apparent maximum dimension of the specimen may not represent its true maximum dimension. The dimensions of the two size classes refer to the basal body ring, not including the radial spines.

The length of the radial spines of *Dictyocha crux* is quite variable. Measurements were taken of the length of the spines in relation to the dimensions of the basal body ring. There was no correlation in the variations of the two measurements. Individuals with identical basal body ring dimensions showed variations of radial spine length from four short to four long in the case of spines of equal length. Those individuals in which the radial spines were in two unequal pairs again showed variation in length, but always with the greater length being in the direction of elongation of the basal body ring when this characteristic was present.

Dictyocha mutabilis Deflandre
Plate 1, figure 9

Dictyocha mutabilis DEFLANDRE, 1950, Microscopie, vol. 2, pp. 69–70, text-figs. 203–204.

Basal body ring elliptical, elongate, slightly inflected in the center at the junction of the lateral rods, with four radial spines in two pairs of unequal length. Basal accessory spines strongly developed and offset from the lateral rods. Apical structure consists of four lateral rods and a single apical bar, which runs perpendicular to the major axis. Length of the major axis 38 microns; width 31 microns. Length of the radial spines of the major axis 8 microns, and of the minor axis 3 microns.

This species is very rare. One specimen was observed in all the samples investigated. The description is based on the single individual, so that variations of this species were not observed.

Dictyocha speculum Ehrenberg

Dictyocha speculum EHRENBERG, 1839, K. Preuss. Akad. Wiss. Berlin, Ber., p. 150; 1854, Mikrogeologie, pl. 18, fig. 57; pl. 19, fig. 41; pl. 21, fig. 44; pl. 22, fig. 47. – STÖHR, 1880, Palaeontographica, vol. 26, p. 120, pl. 7, fig. 8.
Distephanus rotundis STÖHR, 1880, Palaeontographica, vol. 26, p. 121, pl. 7, fig. 9.
Distephanus speculum (Ehrenberg). – HAECKEL, 1887, Rept. Voy. Challenger, Zool., vol. 18, pt. 2, p. 1565. – DEFLANDRE, 1932, Soc. Franç. Microsc., Bull., vol. 1, p. 19, text-figs. 46–49; 1932, Soc. Bot. France, Bull., vol. 79, p. 497, text-figs. 13–20.

Basal body ring with six sides of equal length, with six radial spines of two lengths, one pair long and two pairs short, the longer pair oriented in the axis of basal body ring elongation. Basal accessory spines vary in specimens of the species from prominent to obscure. The apical structure varies considerably in the number and arrangement of the apical apertures, but the number of lateral rods is always equal to the number of sides. Apical accessory spines are present in some specimens and lacking in others of the same type. Surface ornamentation is absent or only slightly developed. Length of the basal body ring 31 microns, width 25 microns. Length of radial spines on the major axis 14 microns, on the minor axis 8 microns.

Dictyocha speculum is the second most abundant species in the samples studied, making up approximately 10 per cent of the total silicoflagellate population. The variation in the apical structure was constant, so that possible varietal forms of the species could be isolated. The forms of *Dictyocha speculum* are as follows:

Dictyocha speculum Ehrenberg, form 1
Plate 1, figures 11–12

Basal body ring, radial spines, basal and apical accessory spines, and lateral rods the same as in the description of the species. The apical structure is composed of two five-sided apical apertures with one common side. The side common to the two apertures is oriented in the direction of one of the two pairs of shorter radial spines.

Dictyocha speculum Ehrenberg, form 2
Plate 1, figures 13, 19

Basal body ring, radial spines, basal and apical accessory spines, and lateral rods the same as in the description of the species. The apical structure is composed of three five-sided apical apertures, with two sides of each in common with adjoining apertures. The common sides of the three apical apertures are oriented so as to align with the direction of alternating radial spines.

Dictyocha speculum Ehrenberg, form 3
Plate 1, figures 14–15

Basal body ring, radial spines, basal and apical accessory spines, and lateral rods the same as in the description of the species. The apical structure is composed of four five-sided apical apertures, with one pair having three sides in common with adjoining apertures and one side in common with the other member of the pair. The second pair has two sides in common with the first pair but no side in common with the other member of the pair. The orientation of the apical structure may be either in the direction of a minor axis (fig. 14) or of the major axis (fig. 15).

Dictyocha speculum Ehrenberg, form 4
Plate 1, figure 16

Basal body ring, radial spines, basal and apical accessory spines, and lateral rods the same as in the description of the species. The apical structure is composed of five five-sided apical apertures, with one aperture having four sides in common with adjoining apertures, with two apertures having three sides in common with adjoining apertures, and with two apertures having two sides in common with adjoining apertures.

Dictyocha speculum Ehrenberg, form 5
Plate 1, figure 17

Basal body ring, radial spines, basal and apical accessory spines, and lateral rods the same as in the description of the species. The apical structure is composed of six five-sided apical apertures, with one central aperture having all sides in common with adjoining apertures, and with five peripheral apertures having three sides in common with adjoining apertures.

Dictyocha speculum Ehrenberg, form 6
Plate 1, figure 18

Basal body ring, radial spines, basal and apical accessory spines, and lateral rods the same as in the description of the species. The apical structure is composed of seven apical apertures, the central aperture being six-sided with all sides in common with adjoining apertures. Peripheral apertures five-sided with three sides in common with adjoining apertures.

Dictyocha speculum Ehrenberg var. septenaria Ehrenberg
Plate 1, figure 20

Distephanus speculum (Ehrenberg) var. *septenarius* (Ehrenberg). – DEFLANDRE, 1932, Soc. Franç. Microsc., Bull., vol. 1, p. 19, text-fig. 48.

Basal body ring with seven sides of equal length, with seven radial spines of two lengths, one pair long and five individual spines shorter and not paired. Basal accessory spines not conspicuous. The apical structure consists of two apical apertures as in *Dictyocha speculum* form 1, but with an additional lateral rod.

TEXT-FIGURE 3
STRATIGRAPHIC RANGE CHART

Dictyocha octonaria Ehrenberg
Plate 1, figure 21

Dictyocha octonaria EHRENBERG, 1854, Mikrogeologie.
Distephanus octonarius (Ehrenberg). – DEFLANDRE, 1932, Soc.
Bot. France, Bull., vol. 79, p. 495, text-figs. 7–12.

Basal body ring with eight sides of equal length, with eight radial spines of equal length. Basal accessory spines not observed. Apical structure consists of eight lateral rods with five apical apertures, as in *Dictyocha speculum* form 4.

Genus MESOCENA Ehrenberg, emend. Deflandre, 1950

Mesocena apiculata (Schulz) Deflandre
Plate 1, figure 10

Mesocena apiculata (Schulz). – DEFLANDRE, 1932, Soc. Bot.
France, Bull., vol. 79, p. 499, text-fig. 35.

Basal body ring triangular with sides slightly arched and inflated, with three small radial spines originating at the corners of the triangle. Surface ornamentation strong. No apical structure present. Length of sides 57 microns; length of radial spines 3 microns. This species constitutes approximately one per cent of the total silicoflagellate population in all samples.

DISCUSSION

The silicoflagellates have received comparatively little attention from paleontologists to date. Deflandre, Frenguelli, Hovasse, Gemeinhardt, Schulz, Marshall, and Borgert have studied these forms from a zoological point of view, with slight attention being given to the stratigraphic value of the group. Fossil material has been studied merely because of the concentration of forms in fossil-bearing sediments rather than for the purpose of stratigraphic application. Hanna (1928) was the first to consider the silicoflagellates as possible guide fossils in stratigraphy.

Text-figure 3 shows the stratigraphic ranges of the eleven known genera of silicoflagellates. The boundary between the Mesozoic and Cenozoic is clearly marked by the disappearance of the genera *Vallacerta, Cornua*, and *Lyramula*, which are index fossils of the Upper Cretaceous. The Paleocene has no characteristic genera to differentiate it, but both *Corbisema* and *Dictyocha* are present. In the future, species of these two genera may possibly be used to mark the Paleocene. The Eocene is characterized by the occurrence of the genus *Naviculopsis*. In the Oligocene, *Paradictyocha* and *Phyllodictyocha* make their first appearance. The Miocene is characterized by the occurrence of the genera *Mesocena* and *Cannopilus*, which are limited to that age. Within the Miocene, the genus *Nothyocha* is limited to the middle only. The silicoflagellates reached their maximum development during

PLATE 1

1–2 *Corbisema trigona* (Zittel) Deflandre: 1, 20μ; 2, 21μ.

3–8 *Dictyocha crux* Ehrenberg: 3–4, 24μ; 5–6, 28μ; 7–8, 32μ.

9 *Dictyocha mutabilis* Deflandre: 38μ.

10 *Mesocena apiculata* (Schulz) Deflandre: 57μ.

11–19 *Dictyocha speculum* Ehrenberg: 11–12, form 1, 32μ; 13, 19, form 2: 13, 32μ; 19, 35μ; 14–15, form 3: 14, 34μ; 15, 35μ; 16, form 4: 35μ; 17, form 5: 26μ; 18, form 6: 37μ.

20 *Dictyocha speculum* Ehrenberg var. *septenaria* Ehrenberg: 36μ.

21 *Dictyocha octonaria* Ehrenberg: 34μ.
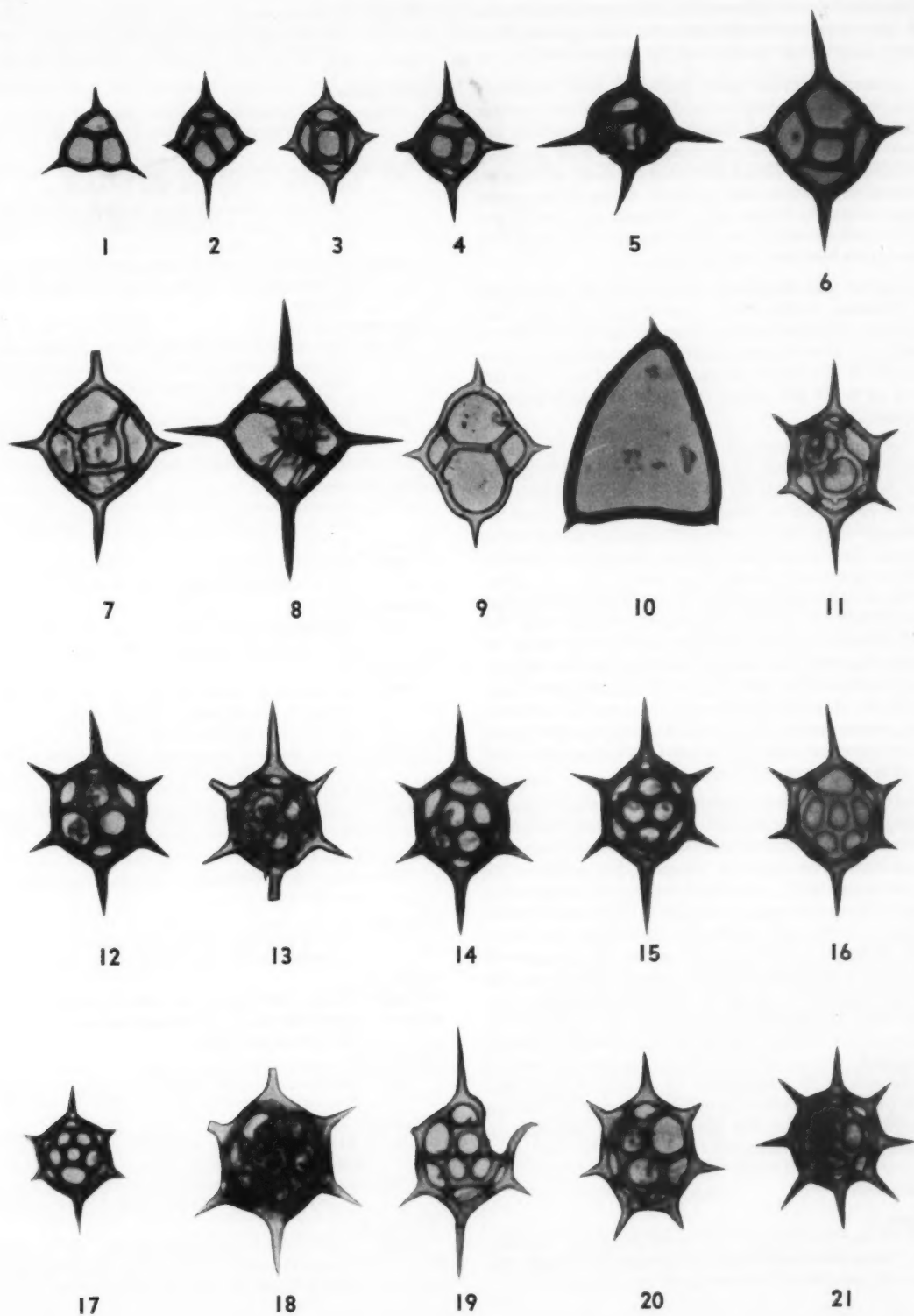
the Miocene. At the close of the Miocene, seven of the eight genera present in the Miocene disappeared, leaving only *Dictyocha* to continue to the present time.

The genera *Corbisema* and *Dictyocha* have extended ranges, so that stratigraphic subdivisions are not possible at the generic level of classification. A statistical approach to the population composition may possibly prove valuable, but in the case of the Calvert sediments, the composition remained constant. *Dictyocha crux* made up approximately 90 per cent, *Dictyocha speculum* 10 per cent, *Dictyocha mutabilis* less than one per cent, and *Corbisema trigona* less than one per cent.

The Calvert silicoflagellates were found in association with diatoms, radiolarians, and sponge spicules. The association remains constant through the first 34 feet of the column. The siliceous microfossil assemblage is very abundant in the lower portion of the column, but decreases up to 34 feet above the base, at which point it disappears.

The specimens described in this study as *Corbisema trigona* actually appear to have as much affinity to the genus *Dictyocha* as they do to *Corbisema*. The scarcity of the type prevented a more critical evaluation, and the specimens were therefore questionably classified as *Corbisema*. *Corbisema trigona* has been described previously only from the Lower Cretaceous, and is the only silicoflagellate so far known to occur in the Lower Cretaceous. If the affinity of *Corbisema trigona* is actually with the genus *Dictyocha*, this fact would extend the range of *Dictyocha* back to the Lower Cretaceous, and restrict that of *Corbisema* to the Upper Cretaceous and later ages. If the Maryland specimens are actually *Corbisema trigona*, as assumed in this study, the range of this species must be extended from the Lower Cretaceous up to and including the Lower Miocene.

A great deal of work is still necessary for a complete understanding of the silicoflagellates and the application of this knowledge to stratigraphy. A considerable amount of work has been done in the past few years in an attempt to establish a practical system of classification of fossil silicoflagellates. Deflandre's 1950 contribution appears to be the only usable system to date, but redefinition of many existing species within the framework of this system is necessary. The pelagic habitat and the temperature-salinity range of the silicoflagellates indicate wide geographic distribution and good stratigraphic potential. The limited geologic ranges of some genera make them index fossils at the generic level of classification. The redefinition of existing species and studies of recovery methods from sediments of various lithologies can make the silicoflagellates valuable in stratigraphic paleontology.

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ABSTRACT: *This study concerns the quantitative and qualitative micropaleontology of the Oldsmar limestone. Five new species and two new varieties of previously known species are described. Biostratigraphic zones established by Applin and Applin are revealed by counts of fossils occurring in well cuttings. The probable environment of deposition of the Oldsmar limestone is indicated by a comparison of lithologic and paleontologic data with similar data on Recent sediments.*

Micropaleontology of the Oldsmar limestone (Eocene) of Florida

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INTRODUCTION

This report presents the observations and interpretations derived from a study of microfossils from the Oldsmar limestone of Florida. The formation is Lower Eocene in age. Material for the study consisted of well cuttings taken from the interval between 1250 and 1750 feet in the Humble Oil & Refining Company's C. E. Robinson No. 1 well. The boring was made at the center of the NE¼ NE¼ sec. 19, T. 16 S., R. 17 E., Levy County, Florida (see Chart 1).

The Oldsmar limestone is known only from the subsurface. Named in 1944 by Applin and Applin, the formation was described as including the dolomitic limestone of Lower Eocene age lying above the Cedar Keys formation of Paleocene age. The top of the formation is marked by the highest occurrence of abundant *Helicostegina gyralis* Barker and Grimsdale. Because of the unfossiliferous nature of the lower portion, the thickness of the Oldsmar limestone is difficult to determine precisely. It has been reported as 500 feet thick in Levy County. The base of the Oldsmar in the C. E. Robinson well is believed by Vernon (1951) to lie at 1750 feet. This interpretation is based on the lithologic change from the crystalline dolomitic limestone of the Oldsmar formation to the chalky dolomite of the Cedar Keys formation.

PREPARATION OF MATERIAL

Satisfactory disaggregation of the samples was accomplished by placing them in the rotating tubes of the Campbell Sample Washer for a period of ten hours. After disaggregation and drying, the samples were passed through a 16-mesh screen. The screened samples were then passed through a micro-splitter to insure a representative sample for picking. A 10-milliliter split from each 10-foot interval of sample was picked until entirely devoid of fossils. The numerical count of each genus and species was then plotted on graph paper.

Because the fauna contains many of the so-called larger foraminifera, it was necessary to employ the additional techniques of thin-sectioning and radiography. The latter technique has been described in detail by Ruth Schmidt (1948, 1952). When adapted to the X-ray photography of larger foraminifera with the apparatus manufactured by the Picker X-ray Corporation, the method involves the following steps:

1) The specimens to be X-rayed are glued to the exterior of an ordinary X-ray film cassette which has been previously loaded with a Kodak spectroscopic plate, type 548–0. Because it will not peel while drying, ordinary mucilage diluted with water will provide a better glue than gum tragacanth. The number of specimens glued to the plate is limited only by the size of the X-ray field. It is therefore entirely possible to photograph over 100 specimens at one time.

2) The cassette with the attached microfossils is placed in a vertical position so as to intercept the horizontally directed radiation at right angles (see text-fig. 1). A distance of eleven inches from target to cassette is recommended when using the copper target tube.

3) The cassette and plate are exposed to X rays for a period of 7 minutes, using 10 milliamperes and 25 kilovolts. These requirements vary according
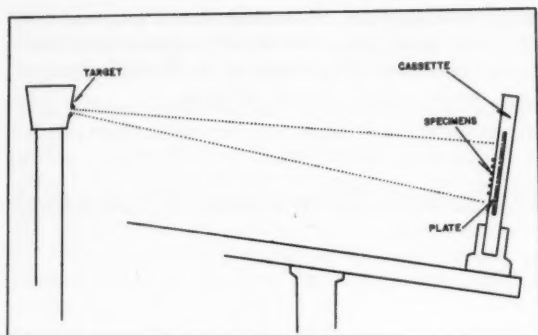
Diagrammatic sketch showing apparatus used in radiography of microfossils.

to the distance from the target tube and the thickness and composition of the specimen. Preliminary tests are therefore essential.

4) After exposure, the plate is removed from the cassette and developed. Directions for developing are usually printed on the labels of the container by the manufacturer.

Many of the larger specimens in the Oldsmar limestone are filled with calcite. As a result, in many cases there is insufficient differential absorption of X rays and therefore lack of contrast on the film. Also, minute features of the wall, such as pores and canals, cannot be seen as readily as in a thin section. On the other hand the number of chambers and their size, shape, and arrangement are clearly visible. When such characters are of specific importance, rapid identifications can be made from X-ray photographs without altering the specimen in any way. In many cases, hours of tedious thin-sectioning can be saved.

STRATIGRAPHY

The Oldsmar limestone represents a carbonate facies of Wilcox age which occurs over most of the state of Florida. In addition, there is a clastic facies found along the northern boundary of the state. This clastic facies is not represented in the C. E. Robinson well, and probably does not occur in Levy County. Lithologically, the Oldsmar presents a monotonous sequence of fossiliferous white dolomitic limestones. However, near the top of the formation, some of the well samples consist of over 75 per cent lignite. The carbonates both above and below this lignite bed contain large amounts of organic debris. In this upper zone, the limestone is visibly crystalline, light brown in color, somewhat cherty, and contains

numerous fillings of selenite. Fine-grained, soft, porous, "mat" dolomitic limestones are interspersed with the crystalline carbonates. At 1290 feet the samples contain considerable detrital quartz. Below 1360 feet the rock becomes gradually less crystalline in nature and gives way to a porous, friable, light gray, "mat" dolomitic limestone.

The name Oldsmar limestone was proposed by Applin and Applin (1944, p. 1698) for the carbonate "interval marked at the top by abundant specimens of *Helicostegina gyralis* Barker and Grimsdale ...that rests on the Cedar Keys formation." It is recognized as equivalent to the main body of the Wilcox group of the Gulf Coast. In the cuttings examined, all four of the zones designated by the Applins were recognized. The zones and their depth locations in the C. E. Robinson well are as follows:

Zone I, the *Helicostegina gyralis* zone, is present at 1250 feet. However, the first "flood" occurrence of *Helicostegina gyralis* is found at 1260 feet. There is a slight decrease in recovery of specimens below 1270 feet, until at 1310 feet large numbers again make their appearance. A "flood" of *Helicostegina gyralis* occurs again at 1360 feet.

Zone II, which the Applins describe as the "Salt Mountain faunal unit," is characterized in the Florida Peninsula by the species *Pseudophragmina (Proporocyclina) cedarkeysensis*. It occurs as a thin zone between 1300 and 1310 feet. In the Humble well, it can actually be considered a subzone of the *Helicostegina gyralis* zone. Also present within this zone are the much smaller forms *Cibicides sassei* and *Asterigerina texana*.

Zone III is designated the *Coskinolina elongata* zone. It extends from 1400 to 1500 feet in the Humble well. At the top, it is further marked by great numbers of *Gyroidina lottensis*, *Nonion mimica* n. sp., and *Quinqueloculina akneriana*.

Zone IV is characterized by the occurrence of *Miscellanea nassauensis* and *Miscellanea nassauensis reticulosus*. The zone extends from 1490 to 1550 feet. Large numbers of *Rotalia trochidiformis* occur within this interval.

Below 1560 feet, all specimens recovered appear to be contaminants from higher levels. The bottom of the Oldsmar limestone, as defined by the Applins, is represented by the highest occurrence of the Cedar Keys sediments. Cole (1944, p. 28) includes in the Cedar Keys formation all the sediments "from the first appearance of the *Borelis* fauna, to the top of the Upper Cretaceous." However, in the C. E. Robinson well, *Borelis floridanus* is present between

SYMBOLS P = Paleocene L = Lower Eocene M = Middle Eocene	FLORIDA	ALABAMA & LOUISIANA	TEXAS	WEST INDIES	MEXICO & PANAMA	ARABIA	WEST EUROPE
VALVULINA SP.	L						
COSKINOLINA ELONGATA	L & M						
QUINQUELOCULINA AKNERIANA	L				L		L-Rec
NONION MIMICA n. sp.	L						
CAMERINA SP.	L						
MISCELLANEA NASSAUENSIS	L			L			
MISCELLANEA NASSAUENSIS var. RETICULOSIS	L						
BORELIS FLORIDANUS	P & L						
TUBULOGENERINA TURBINA n. sp	L						
DISCORBIS INORNATUS	M						
DISCORBIS TALLAHATTENSIS	M	M					
DISCORBIS YEGUAENSIS	M	M	M				
GYROIDINA LOTTENSIS var. IMPENSA n. var.	'L						
GYROIDINA LOTTENSIS	L	L					
EPONIDES OLDSMARENSIS n. sp.	L & M						
ROTALIA TROCHIDIFORMIS	L					L	M
LOCKHARTIA GYROPAPULOSA n. sp.	L						
LOCKHARTIA PRAEALTA n. sp.	L						
SIPHONINA WILCOXENSIS	L	P & L					
ASTERIGERINA PRIMARIA var. HELIGMA n. var.	L						
ASTERIGERINA TEXANA	L	M	M				
HELICOSTEGINA GYRALIS	L			L & M	L & M		
AMPHISTEGINA LOPEZTRIGOI	L & M			M			
CIBICIDES SASSEI	L & M	M	M		M		
PSEUDOPHRAGMINA (PROPOROCYCLINA) CEDARKEYSENSIS	L			L			
AULOCYTHERIDEA MARGODENTATA	M						
HAPLOCYTHERIDEA cf. GOOCHI	M						
XESTOLEBERIS SP	L						
CYTHEREIS ? LONGICOSTATA	M	M					

TEXT-FIGURE 2
DISTRIBUTION OF MICROFOSSILS

1430 and 1500 feet. At this location, therefore, the species occurs in the lower part of Zone III and at the top of Zone IV, within the Oldsmar limestone.

The Oldsmar limestone is overlain by the Lake City limestone. Some of the Middle Eocene species that occur rarely in the upper part of the Oldsmar well cuttings are probably derived by caving or recirculation from the overlying Lake City limestone.

As a member of the Wilcox group, the Oldsmar limestone can be readily correlated with many well-known Gulf Coast and Caribbean formations. Although conditions of deposition were obviously different, the Oldsmar can be considered a time equivalent of the Wilcox of Mexico and the Salt Mountain formation of Alabama. Vaughan (1945, p. 18) has reported beds of similar age on the island of Barbados. These Barbadian beds in turn may be correlated with beds of similar age in Puerto Rico (Kaye, 1956, p. 108), near the town of Loiza.

The species *Helicostegina gyralis* has been found by Cole and Gravell (1952) in Matanzas Province, Cuba. The deposits from which the specimens were recovered are believed to be correlatives of the Lake City limestone.

139

Cole and Bermudez (1947, p. 5) have reported *Pseudophragmina (Proporocyclina) cedarkeysensis* from Cuban beds of "either Middle or high Lower Eocene age." The Oldsmar has also been correlated with portions of the Lower Eocene sediments of Trinidad.

It is apparent that the Oldsmar fauna is more readily correlated with the microfaunas of Cuba, the West Indies, and Mexico than it is with those of adjacent areas of the Gulf Coast. The differences in the depositional environments of the two areas account for this lack of biological correlation. The area to the northwest of Florida was an actively subsiding trough during most of Oldsmar deposition. The peninsula of Florida, on the other hand, was a shallow, stable, submerged shelf undergoing carbonate deposition. The waters off the coast of Mississippi, Louisiana, and Texas were more turbid and received great volumes of detrital sediments. As a result, entirely different faunal assemblages developed.

Although there are few species common to beds of identical age in Florida and in the Qatar Peninsula of Arabia, it is nonetheless interesting to note the similarities in the general faunal aspects of these two areas. *Rotalia trochidiformis* is common in the Lower Eocene of Qatar, and the Florida specimens of *Lockhartia* are very similar to the Arabian forms. Certainly a close similarity in ecological conditions must have existed during the Lower Eocene at these two widely separated localities.

The geographic and stratigraphic distribution of specimens recovered from the C. E. Robinson well are summarized in text-figure 2.

ECOLOGY

In spite of the considerable amount of data already assembled concerning the ecology of fossil organisms, there is still a lack of definite knowledge of the living habits of particular species. In the majority of cases, fossil forms have no living counterparts for direct comparison. In such instances, only the morphological characteristics of the test and the nature of the matrix sediment can provide clues to the living habits of the organism. Often, when living counterparts do exist, they are so variable in their choice of environments that they are practically useless in paleoecological studies. Despite these difficulties, a picture of the environment of deposition can still be obtained by careful use of the data at hand coupled with a controlled imagination.

The quantitative approach to the study of the foraminifera of the Oldsmar limestone has a twofold purpose. First, it provides stratigraphic guide zones

according to occurrences of large numbers of fossils at given depths. Secondly, it furnishes a sufficient number of specimens to guard against false interpretation based on contamination.

A simple direct count has the advantage of ease of correlation with the research of other workers. The importance of such correlation has often been overlooked. Percentage methods are not always useful, since, as explained by Said (1950, p. 13), "The disadvantages of the percentage method of representation become obvious when the frequencies of the different species are traced from one locality to another. This is due to the fact that total numbers of specimens in all samples are reduced to 100 irrespective of whether the sample is rich or poor in foraminifera. Thus small numbers of one species in a poor sample will be a high percentage, while a large number of the same species in a rich sample will be a low percentage."

INTERPRETATIONS
Ecological Unit I

The earliest ecological unit in the interval studied begins at 1750 feet and extends upward to about 1540 feet. This interval can be considered as a unit because of similarity of lithology and the relative lack of fossils. *Rotalia trochidiformis* (Lamarck) and *Coskinolina elongata* Cole are probably the only microfossils indigenous to these sediments. Other forms in the interval show sporadic occurrence and very likely represent contaminants from higher levels.

The limestones deposited in this early portion of the Eocene represent warm-water deposits of the shallow Floridian submarine bank which covered most of the state during the early Cenozoic. Apparently, the low island known to have existed over the present central area of Florida during the late Eocene and part of the Miocene was not yet emergent at this locality. The paucity of fossils indicates that much of the limestone may have been directly precipitated. Conditions conducive to such precipitation would be met by the probable high temperature of the water, its undiluted salinity, and, perhaps, the activity of plants on the shallow bottoms. As far as can be deciphered from the cuttings, the dolomite appears to be a secondary replacement. It occurs in small porous patches and fillings of fissures and seams in the limestone. In addition, a number of the larger foraminifera appear to have been completely dolomitized.

An extremely meager insoluble residue, consisting of crystals of gypsum and a few tiny grains of quartz, lends credence to the hypothesis of a shallow

LITHOLOGIC, ELECTRIC, AND QUANTITATIVE FAUNAL LOGS OF THE OLDSMAR LIMESTONE

WITH ECOLOGICAL DEPTH ESTIMATION

HUMBLE OIL AND REFINING CO., C.E. ROBINSON NO. 1, LEVY CO., FLORIDA.

AMPHISTEGINA LOPEZTRIGOI

DEPTH	LITHOLOGY	SELF POTENTIAL −20MV +20MV	SHORT NORMAL RESISTIVITY	
1250 − 60	LIMESTONE, DOLOMITIC, CONSISTING OF MAT, CRYPTOCRYSTALLINE CALCITE, RARE SELENITE.			37
1260 − 70	LS, SAME AS ABOVE, WITH LIGNITE; GASTROPOD AND BRYOZOAN DEBRIS.			132
1270 − 80	LIGNITE AND POROUS, MAT, DOLOMITIC LIME-STONE; BRYOZOAN & ECHINOID FRAGMENTS			16
1280 − 90	LS, WHITE, POROUS MAT, AND PALE, BROWN CALCITE; QUARTZ GRAINS, RARE LIGNITE.			16
1290 − 00	LS, DOLOMITIC, WITH LIGNITE AND ORGANIC DEBRIS.			35
1300 − 10	LIGNITE, AND POROUS, DOLOMITIC, FOSSILIFEROUS LS.			100
1310 − 20	LIGNITE, WITH PALE BROWN, MICRO-CRYSTALLINE, FOSSILIFEROUS LS.			136
1320 − 30	LS, DOLOMITIC, FERRUGINOUS, MICROCRYSTALLINE, WITH SELENITE GYPSUM.			64
1330 − 40	LS, POROUS, WHITE, FOSSILIFEROUS, WITH RARE GRAINS OF QUARTZ, RARE LIGNITE.			27
1340 − 50				22
1350 − 60				162
1360 − 70				21
1370 − 80	LS, FOSSILIFEROUS, POROUS, WHITE MAT, WITH PALE BROWN, MICROCRYSTALLINE CALCITE. COMMON ORGANIC DEBRIS OF ECHINOID SPINES AND BRYOZOAN FRAGMENTS.			190
1380 − 90				93
1390 − 00			RUN TWO SCALE	44
1400 − 10		RUN ONE	20 200	30
1410 − 20	LS, DOLOMITIC, BOTH POROUS MAT AND LIGHT GRAY, LITHOGRAPHIC.			8
1420 − 30	LS, LIGHT GRAY, LITHOGRAPHIC; CALCITE CAVITY FILLINGS; SECONDARY QUARTZ.	RUN TWO		
1430 − 40	LS, LIGHT GRAY POROUS MAT AND LS, LIGHT BROWN, MICROCRYSTALLINE.			
1440 − 50	LS, SAME AS ABOVE, WITH SELENITE.			4
1450 − 60	LS., FOSSILIFEROUS, WHITE, POROUS MAT			
1460 − 70				
1470 − 80				
1480 − 90				
1490 − 00				
1500 − 10	LS, FOSSILIFEROUS, WHITE, POROUS MAT WITH ABUNDANT SELENITE GYPSUM.			1
1510 − 20				
1520 − 30				
1530 − 40	LS, WHITE AND LIGHT BROWN, WITH SELENITE AND SATINSPAR.			
1540 − 50				
1550 − 60				
1560 − 70	LS, WHITE, MICROCRYSTALLINE AND MAT.			
1570 − 80	LS., WHITE, CRYPTOCRYSTALLINE.			
1580 − 90				1
1590 − 00				
1600 − 10	LS., SAME AS ABOVE, WITH GYPSUM AND ABUNDANT FOSSIL DEBRIS.			1
1610 − 20				
1620 − 30	LS, WHITE, POROUS, MAT.			1
1630 − 40	LS, WHITE, VERY POROUS, FRIABLE MAT; ABUNDANT FOSSIL DEBRIS.			
1640 − 50	LS, DOLOMITIC, LIGHT BROWN, MICRO-CRYSTALLINE, WITH ABUNDANT GYPSUM.			
1650 − 60				
1660 − 70	LS., DOLOMITIC, WHITE, POROUS MAT, WITH ABUNDANT GYPSUM AND RARE PYRITE.			
1670 − 80				
1680 − 90				1
1690 − 00				
1700 − 10	LS, DOLOMITIC, UNFOSSILIFEROUS, WHITE, POROUS MAT.			
1710 − 20			ELECTIC LOGS CONTRIBUTED BY HUMBLE OIL AND REFINING CO.	3
1720 − 30				
1730 − 40	LIMESTONE, SAME AS ABOVE, WITH GRAY, MICROCRYSTALLINE LS.			1
1740 − 50	LIMESTONE, LIGHT GRAY, POROUS, DOLOMITIC.			

C.E. RO WEL

LOC

LOGS OF THE OLDSMAR LIMESTONE

ESTIMATION

DA.

POTENTIAL + 20MV	SHORT NORMAL RESISTIVITY

AMPHISTEGINA
LOPEZTRIA...

37
132
16
16
36
100
136
64
27
227
162
270
190
96
44

RUN TWO SCALE

RUN ONE   20

                                 200

30
8

WO

4

1

1
1
1

ELECTIC LOGS
CONTRIBUTED BY HUMBLE
OIL AND REFINING CO.

1

3

1

Column headers (left to right):

AMPHISTEGINA LOPEZTRIGOI · CIBICIDES SASSEI · HELICOSTEGINA GYRALIS · ASTERIGERINA TEXANA · EPONIDES OLDSMARENSIS · CAMERINA SP · PSEUDOPHRAGMINA (PROPORROCYCLINA) CEDARENSIS · COSKINOLINA ELONGATA · GYROIDINA LOTTENSIS IMPENSA · GYROIDINA LOTTENSIS · NONION MIMICA · ASTERIGERINA PRIMARIA HELIOMA · QUINQUELOCULINA ANNERIANA · XESTOLEBERIS · BOLELIS FLORIDANUS · ROTALIA TROCHIOFORMIS · MISCELLANEA NASSAUENSIS · MISCELLANEA NASSAUENSIS RETICULOSIS · TUBULOGENERINA TURRIS · LOCKHARTIA GYROPAPULOSA · LOCKHARTIA PANELLA

LOCATION MAP

LEVY CO.   0   10 mi

C.E. ROBINSON WELL NO. 1

GULF OF MEXICO

FLORIDA

0   50 mi

CIBICIDES SASSEI	HELICOSTEGINA GYRALIS	ASTERIGERINA TEXANA	EPONIDES OLSSMARENSS	CAMERINA SP	PSEUDOPHRA... (PROOLOG... GEO...)
35	15	62	13	3	
8	41	18	18	6	
9	17	16	3	4	
6	10	31	2		26
27	13	32	2		44
6	10	2		17	10
6	42	5	1		
	25				
1	32	164			
3	46	8	1	4	
1	52	4		16	
3	64	4			
13	50	5		3	
15	28			2	
5	13	26			1
	6	7			
					2

1

LEVY CO.

0   10mi

ROBINSON ... NO. 1

GULF OF MEXICO

FLORIDA

0   50mi

...SATION
MAP

CHART 1

(rotated column headers)
CAMERINA SP
PSEUDOPHRAGMINA (PROPOROCYCLINA) CEDARKEYENSIS
COSKINOLINA ELONGATA
GYROIDINA LOTTENSIS IMPENSA
GYROIDINA LOTTENSIS
NONION MIMICA
ASTERIGERINA PRIMARIA HELISMA
QUINQUELOCULINA ANNERIANA
XESTOLEBERIS
BOUEUS FLORIDANUS
ROTALIA TROCNIDIFORMIS
MISCELLANEA NASSAUENSIS
MISCELLANEA NASSAUENSIS RETICULOSIS
TUBULOGENERINA TURBINA
LOCHARTIA GYROPAPULOSA
LOCHARTIA PRAEALTA

RARE OCCURRENCE

ECOLOGICAL DEPTH ESTIMATE		
INNER NERITIC	OUTER NERITIC	BATHAL

Rare occurrence entries (top to bottom):
- DISCORBIS INORNATUS (1)
- DISCORBIS YEGUAENSIS (3)
- CYTHEREIS? LONGICOSTATA (1)
- QUINQUELOCULINA SP. (1)
- DISCORBIS YEGUAENSIS (2)
- SIPHONINA WILCOXENSIS (1)
- SIPHONINA WILCOXENSIS (1)
- AULOCYTHERIDEA MARGODENTATA (1)
- DISCORBIS TALLATTENSIS (1)
- VALVULINA SP.
- QUINQUELOCULINA SP. (1)
- SIPHONINA WILCOXENSIS (1)
- DISCORBIS YEGUAESIS (1)
- SIPHONINA WILCOXENSIS (1)
- QUINQUELOCULINA SP. (1)
- HAPLOCYTHERIDEA cf. GOOCHI (1)

shelf sea at the beginning of Oldsmar deposition. The average depth of water probably did not exceed 70 meters.

Ecological Unit II

In the interval between 1550 and 1450 feet, fossils begin to be abundant in the sediment. *Coskinolina elongata* has its maximum occurrence between 1450 and 1460 feet. Over seventy specimens were recovered. *Miscellanea nassauensis, Miscellanea nassauensis reticulosus, Tubulogenerina turbina, Lockhartia praealta,* and *Lockhartia gyropapulosa* occur within this faunal unit. In addition, there are large numbers of *Rotalia trochidiformis.* In the interval between 1500 and 1510 feet, for example, 263 specimens were taken from one 10-milliliter sample.

Rotalia trochidiformis is an extinct species. However, its large size and heavy construction suggest that it probably preferred depths of 20 to 40 meters. In this shallow water, light penetration and food availability are normally excellent. It appears that an analogy can be made between *Rotalia trochidiformis* and similar shallow-water species which Myers (1942 *a*, p. 38) describes as "large species of *Rotalia* having biconvex but not bilaterally symmetrical tests that rest on what is usually referred to as the dorsal surfaces."

The occurrence of lignite in the insoluble residue supports the paleontological evidence of the existence of a warm, shallow tropical or subtropical sea during the deposition of the second ecological unit.

Ecological Unit III

Another distinct environmental unit was encountered between 1450 and 1400 feet. In this interval, *Coskinolina* continues as a common member of the fossil assemblage, but becomes suddenly very rare above 1410 feet. Simultaneously, large numbers of smaller forms such as *Gyroidina lottensis, Nonion mimica, Asterigerina primaria heligma, Quinqueloculina akneriana,* and the ostracode *Xestoleberis* make their appearance.

Quinqueloculina akneriana has been reported at depths ranging from 38 to 374 meters and at temperatures between 13.2° C. and 8.5° C. (Glaessner, 1945). Although the genus *Nonion* has been found at all depths in the ocean, the majority of recent studies assign to it a depth not exceeding 2000 meters. *Gyroidina* is another genus with a wide environmental range. However, here again, the genus is found most commonly in the deeper waters. Phleger and Parker (1951, pp. 54–60) report species of *Gyroidina* from depths between 500 and 2300 meters. Crouch (1952, pp. 809–810) has noted members of the genus

at 1200 to 2300 meters. Species of the ostracode genus *Xestoleberis* have been reported by Müller (1912, pp. 295–304) at depths ranging from 30 to 3000 meters.

These data, on the whole, suggest a change from a neritic to a bathyal environment. An increase in the depth of water of at least 700 to 900 meters over the previous environmental unit is indicated.

Ecological Unit IV

The uppermost ecological interval embraces the beds from 1400 to 1250 feet. The environment of deposition is indicated as predominantly shallow warm water of the neritic zone. Lignite is an abundant constituent of the sediment, and occurs at both 1270 and 1300 feet. The insoluble residue reveals numerous worn grains of quartz. It seems probable that a low-lying land area may have existed nearby, perhaps as a gently emergent flexure in the Ocala uplift. Such a tectonically positive area could be considered as the source of the plant debris carried into the hypothetical swampy coastal regions during late Oldsmar time. Such debris can be considered the source material for the lignite occurring in this unit.

The principle foraminiferal members of the biotope are the following:

> *Amphistegina lopeztrigoi*
> *Helicostegina gyralis*
> *Nummulites* sp.
> *Pseudophragmina (Proporocyclina) cedarkeysensis*
> *Asterigerina texana*
> *Eponides oldsmarensis* n. sp.

Considerable ecological information has been accumulated in reference to larger foraminifera such as *Amphistegina lopeztrigoi, Helicostegina gyralis,* and *Pseudophragmina.* Vaughan (1945, pp. 21–22) and Glaessner (1945, p. 188) indicate that Recent species of *Amphistegina* are abundant in warm, shallow, inshore shoal waters. Myers (1941, p. 43) has noted that the large Amphisteginidae, as well as other large foraminifera, thrive near reef areas which support a heavy growth of macroflora. In reference to foraminifera of the sublittoral zone, Myers has further noted that "because conditions are more stable and food more abundant, tests are larger, walls thicker, and the need for a visible means of attachment is reduced."

With regard to forms similar to *Pseudophragmina,* Myers (1943) points out that foraminifera having such discoidal tests are most commonly limited to the sublittoral zone. Vaughan (1945) appears to be in complete agreement with this interpretation.

The smaller species of *Asterigerina* within the fourth ecological unit occur at intervals marked by a decrease in the lignite content and a reduction in the numbers of large Amphisteginidae. It can be assumed that the presence of *Asterigerina* may represent a slight deepening of the water. However, since Recent species of *Asterigerina* and *Eponides* are not often found in water deeper than 100 meters, the hypothesis of a warm, neritic-zone environment is not seriously challenged.

Another interesting phenomenon occurs in the samples from 1250, 1280, 1290, and 1330 feet. At these depths the normally large species of the Amphisteginidae are replaced by depauperate forms of the same species. In general, these forms are smaller by an average of 0.3 mm. Their surface pustules are smaller and more delicate. The walls of the test are distinctly less robust. At the four depths indicated, there is also a decrease in the content of lignite and an increase in the abundance of the slightly deeper-water species *Asterigerina texana*. The combination of these three phenomena is suggestive of a deepening of the water, with a corresponding possible decrease in food supply. This interpretation is advanced with caution. Other factors, such as reduction in food supply due to overgrazing by other organisms, seasonal shift of isotherms, or simply increase in accessibility to the open sea, might account for the size decreases. As always, there is the possibility of the mixing of faunal elements under the influence of currents.

SYSTEMATIC DESCRIPTIONS

In the following section, only new forms will be described in detail. Holotypes and figured specimens will be deposited in the U. S. National Museum, Washington, D.C. Topotypic material remains in the micropaleontological collection of Washington University, Saint Louis, Missouri, and is catalogued under the serial numbers W.U.F.C. 000001 to 000022.

<div align="center">

Phylum PROTOZOA

Order FORAMINIFERA

Family VALVULINIDAE

Genus VALVULINA d'Orbigny, 1826

Valvulina sp.
Plate 1, figure 1

</div>

Test moderately slender, distinctly arenaceous with high content of carbonate cement; early chambers triserial, later chambers loosely arranged in an elongate spiral; chambers in the initial triserial portion of the test forming a plane surface, later chambers strongly inflated and separated by depressed sutures; aperture at the inner margin of the terminal chamber, elongate, and provided with a long, thin tooth. Diameter 0.300 mm.; length 1.500 mm.

This form appears similar to *Valvulina intermedia* Applin and Jordan (1945, p. 134), and may represent a precursor of that species. It differs in its more pronounced tooth, the lack of the cribrate apertural tendencies discussed by Applin and Jordan, and the smaller number of chambers. A single specimen was recovered at a depth of 1340 feet. As a result, it does not seem advisable to name a new species.

<div align="center">

Genus COSKINOLINA Stache, 1875

Coskinolina elongata Cole
Plate 1, figures 2–3

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Coskinolina elongata COLE, 1942, Florida, Geol. Survey, Bull., no. 20, p. 18, pl. 3, figs. 15–17; pl. 4, figs. 2–7; pl. 16, fig. 6. – APPLIN AND APPLIN, 1944, Amer. Assoc. Petr. Geol., Bull., vol. 28, no. 12, pl. 4, fig. 5.

Coskinolina elongata occurs in great abundance between 1450 and 1460 feet, representing the *Coskinolina elongata* zone erected by Applin and Applin (1944, p. 1699). Sporadic occurrences below these depths are believed to be contaminations. The species occurs in the lower Middle Eocene and Lower Eocene of Levy County, Florida.

<div align="center">

Family MILIOLIDAE

Genus QUINQUELOCULINA d'Orbigny, 1826

Quinqueloculina akneriana d'Orbigny
Plate 1, figures 11–12

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Quinqueloculina akneriana D'ORBIGNY, 1846, Foram. Foss. Vienne, p. 290, pl. 18, figs. 16–21. – GALLOWAY AND HEMINWAY, 1941, New York Acad. Sci., Sci. Survey Porto Rico and Virgin Islands, vol. 3, pt. 4, p. 301, pl. 2, fig. 1a–c. – MARKS, 1951, Cushman Found. Foram. Res., Contr., vol. 2, pt. 2, p. 38.
Quinqueloculina triangularis D'ORBIGNY, 1846, Foram. Foss. Vienne, p. 288, pl. 18, figs. 7–9.
Quinqueloculina mayeriana D'ORBIGNY, 1846, ibid., p. 287, pl. 18, figs. 1–3.
Quinqueloculina hauerina D'ORBIGNY, 1846, ibid., p. 286, pl. 17, figs. 25–27.
Quinqueloculina regularis REUSS, 1850, K. Akad. Wiss. Wien, Denkschr., vol. 1, p. 384, pl. 50, fig. 1.
Quinqueloculina concinna REUSS, 1850, ibid., p. 384, pl. 50, fig. 2.
Quinqueloculina impressa REUSS, 1851, Deutsch. Geol. Ges., Zeitschr., vol. 3, p. 87, pl. 7, figs. 5–9.
Quinqueloculina ermani BORNEMANN, 1855, ibid., vol. 7, p. 353, pl. 19, fig. 6.
Quinqueloculina ovalis BORNEMANN, 1855, ibid., p. 353, pl. 19, fig. 9.
Miliolina seminulum (Linné). – BRADY, 1884, Rept. Voy. Challenger, Zool., vol. 9, pl. 5, fig. 6.
Quinqueloculina seminulum (Linné). – CUSHMAN, 1918, U. S. Nat. Mus., Bull. 103, p. 78, pl. 28, fig. 1a–c (not figs. 2–3). – CUSHMAN, 1929, U. S. Nat. Mus., Bull. 104, pt. 6, p. 24, pl. 2, figs. 1–2.

The species occurs rarely between 1390 and 1410 feet. Its recorded range is from Lower Eocene to Recent.

Quinqueloculina sp. indet.

The single specimen obtained from the Humble well appears to be either an external cast or a completely recrystallized form. Specific designation was not possible. The specimen was found at a depth of 1270 feet.

Family NONIONIDAE

Genus NONION Montfort, 1808

Nonion mimica Levin, new species
Plate 1, figures 7–10

Test involute, planispiral, slightly longer than wide, thickest across the last-formed chamber, close-coiled, bilaterally symmetrical; umbilicus shallow, obscure, with irregular filling of fine papillose shell material; periphery rounded; chambers distinct and inflated, nine to eleven chambers in the final volution; sutures gently curved toward the posterior, depressed; wall thin, perforate; aperture a thin, arched slit at the base of the last-formed chamber. Height of figured specimen 0.437 mm.; width 0.375 mm.; thickness 0.187 mm. The largest specimens are as much as 0.5 mm. in height, and the smallest 0.29 mm. in height.

Nonion mimica appears as a short-ranging but distinctive species in the middle portion of the Oldsmar limestone. It differs from the earlier species *Nonion planatum* in the closer spacing of septa, the larger size, and the depressed sutures. This species is found in greatest abundance between 1390 and 1400 feet in the Humble well.

Family NUMMULITIDAE

Genus NUMMULITES Lamarck, 1801

Nummulites sp.
Plate 1, figures 4–6

The specimens of *Nummulites* from the Oldsmar limestone are badly eroded, giving the appearance of having been reworked. As a result, the peripheral area of the test often stands out as a residual marginal ridge. The true aperture could not be observed. In general, the Oldsmar forms are smaller and more rotund than either *Nummulites guayabalensis* or *Nummulites moodybranchensis*. Further work with better specimens may reveal that the Florida forms are varieties of one of these species.

Nummulites sp. occurs in the Humble well from 1290 to 1380 feet.

Genus MISCELLANEA Pfender, 1934

Miscellanea nassauensis Applin and Jordan
Plate 2, figures 1–2

Miscellanea sp., APPLIN AND APPLIN, 1944, Amer. Assoc. Petr. Geol., Bull., vol. 28, no. 12, pl. 4, fig. 1a–b.
Miscellanea nassauensis APPLIN AND JORDAN, 1945, Jour. Pal., vol. 19, no. 2, p. 139, pl. 19, fig. 4a–b. – APPLIN AND JORDAN, 1950, Jour. Pal., vol. 24, no. 4, p. 477.

Miscellanea nassauensis occurs in greatest abundance at 1510 feet in the C. E. Robinson well.

Miscellanea nassauensis Applin and Jordan var. reticulosus Applin and Jordan
Plate 1, figures 13–14

Miscellanea nassauensis Applin and Jordan var. *reticulosus* APPLIN AND JORDAN, 1945, Jour. Pal., vol. 19, no. 2, p. 140.

Applin and Jordan (1945, p. 140) described but did not figure this variety. Fortunately, the specimens recovered from the Humble well conform closely to the description and occurrence as indicated by the authors. The variety occurs abundantly between 1490 and 1510 feet.

Family ALVEOLINELLIDAE

Genus BORELIS Montfort, 1808

Borelis floridanus Cole
Plate 2, figures 3–4

Borelis gunteri Cole var. *floridana* COLE, 1941 (part), Florida, Geol. Survey, Bull., no. 19, p. 35, pl. 18, figs. 3–4 (not figs. 7–8).
Borelis floridanus Cole. – COLE, 1944, Florida, Geol. Survey, Bull., no. 26, p. 53, pl. 9, figs. 1–5.

The specimens obtained are typical of those described by Cole (1941, p. 35) from the Eocene of Florida. They occur in the interval between 1430 and 1500 feet.

Family BULIMINIDAE

Genus TUBULOGENERINA Cushman, 1927

Tubulogenerina turbina Levin, new species
Plate 2, figures 5–8

Test elongate, conical; early stages appear triserial, but test is uniserial in the later four-fifths; chambers number six to eight in the uniserial portion of the test; wall calcareous, perforate, thick, and pierced by tiny canals radiating outward from the interior portion of the test; ornamentation consists of rows of pustules which circumscribe each chamber; the pustules are elongate parallel to the long axis of the test, and are in vertical alignment. Thin sections reveal that the floor of each chamber is connected with those above by a central cylindrical core of shell material; the aperture is usually obscure because of erosion, but may appear as a gently crescent-shaped slit on the terminal face superjacent to the internal core. Length 0.690 mm.; thickness 0.439 mm.

The only species resembling *Tubulogenerina turbina* is the form described by Howe (1934, p. 420) under the name *Tubulogenerina jacksonensis*. Those specimens are considerably smaller than the Oldsmar form, and lack the rounded terminal face and more conical shape. The ornamentation, however, appears to be very similar in the two species. *Tubulogenerina turbina* was found in the Robinson well between 1450 and 1460 feet.

Family ROTALIIDAE

Genus DISCORBIS Lamarck, 1804

Discorbis inornatus Cole
Plate 2, figures 9–11

Discorbis inornatus COLE, 1942, Florida, Geol. Survey, Bull., no. 20, p. 30, pl. 1, figs. 1–3. – APPLIN AND APPLIN, 1944, Amer. Assoc. Petr. Geol., Bull., vol. 28, no. 12, pl. 3, fig. 7a–c (figured only).

Only one specimen of *Discorbis inornatus* was found in the Humble well. However, the specimen is well preserved, and identification is positive. The specimen, which occurs in the interval between 1250 and 1260 feet, is probably a contamination from the Lake City limestone.

Discorbis tallahattensis Bandy
Plate 2, figures 15–16

Discorbis tallahattensis BANDY, 1949, Bull. Amer. Pal., vol. 32, no. 131, p. 97, pl. 16, fig. 7a–c.

A single specimen of *Discorbis tallahattensis* was recovered from the interval between 1340 and 1350 feet. It is smaller than, and lacks the prominent valvular flap of the Stave Creek form. Nevertheless, it bears a close affinity in all other features. The erection of a new species or variety does not appear justified.

Discorbis yeguaensis Weinzierl and Applin
Plate 1, figures 15–17

Discorbis yeguaensis WEINZIERL AND APPLIN, 1929, Jour. Pal., vol. 3, no. 4, p. 405, pl. 44, fig. 5a–c. – CUSHMAN AND THOMAS, 1930, Jour. Pal., vol. 4, no. 1, pl. 4, fig. 1a–c. – BANDY, 1949, Bull. Amer. Pal., vol. 32, no. 131, p. 99, pl. 17, fig. 2a–c.

Three specimens of *Discorbis yeguaensis* were found in the samples examined. They were all poorly preserved, and may represent cavings from a higher bed in the section.

Genus GYROIDINA d'Orbigny, 1826

Gyroidina lottensis Garrett
Plate 2, figures 12–14

Gyroidina lottensis GARRETT, 1941, Jour. Pal., vol. 15, no. 2, p. 155, pl. 26, fig. 11a–c.

Gyroidina lottensis was originally described by Garrett (1941, p. 155) from sediments of Nanafalia age (Wilcox Eocene) in Alabama. In the C. E. Robinson well, it is restricted to the interval between 1390 and 1400 feet, in the Oldsmar formation.

Gyroidina lottensis Garrett var. impensa Levin, new variety
Plate 2, figures 17–19

Test trochoid, biconvex, slightly higher than wide; periphery slightly lobate in the last four or five chambers, gently rounded; chambers slightly inflated on ventral side, not inflated dorsally; there are eight or nine chambers in the final volution, and a total of fourteen to sixteen chambers visible on the dorsal surface; umbilical area depressed, often with irregular fillings of secondary shell material; sutures thick, depressed ventrally, flush with the dorsal surface; wall calcareous, finely perforate; aperture an elongate slit at the base of the last-formed chamber, extending from the periphery toward the umbilicus. Height 0.572 mm.; width 0.473 mm.; thickness 0.325 mm.

This variety differs from *Gyroidina lottensis* as described by Garrett (1941, p. 155) in its greater height in relation to width, in the larger and longer terminal chamber, and in its larger size. The average specimen is twice the diameter of the form described by Garrett. The variety is abundant in the interval between 1390 and 1400 feet.

Genus EPONIDES Montfort, 1808

Eponides oldsmarensis Levin, new species
Plate 2, figures 20–22

Test small, calcareous, perforate, biconvex; periphery subacute and smooth, with a tendency toward a bluntly rounded keel; dorsal surface smooth, showing nine to ten chambers; sutures strongly curved toward the posterior, becoming indistinct in the umbonal area; ventral surface smooth, with a prominent spiral suture delineating two and one-half to three volutions; aperture not observed, but on broken specimens appears to be an elongate opening at the base of the last-formed chamber on the ventral side.

This species occurs in the upper part of the Oldsmar limestone in small but persistent numbers. In contrast to *Eponides mexicanus*, it lacks the peripheral lobulation and the limbate dorsal sutures of that species. Also, there is no raised rim around the umbilicus as is the case in *Eponides mexicanus*. *Eponides oldsmarensis* has its maximum occurrence in the interval between 1250 and 1260 feet.

Genus ROTALIA Lamarck, 1804

Rotalia trochidiformis (Lamarck)
Plate 3, figures 1–4

Rotalites trochidiformis LAMARCK, 1804, Paris, Mus. National Hist. Nat., Ann., vol. 5, p. 184; 1806, ibid., vol. 8, pl. 62, fig. 8a–b.
Rotalia trochidiformis (Lamarck). – DESHAYES, 1832, Encyclopédie Méthodique; Histoire Naturelle des Vers, vol. 3, p. 912. – DAVIES, 1932, Roy. Soc. Edinburgh, Trans., vol. 57, pt. 2, no. 13, pp. 416–418, pl. 2, figs. 8, 10–15; pl. 3, figs. 1–13; pl. 4, figs. 3–6, 9–11; text-figs. 6, 8–9. – PFENDER, 1935, Soc. Géol. France, Bull., ser. 5, vol. 4, fasc. 4–5, p. 234, pl. 13, fig. 1. – SMOUT, 1954, *Lower Tertiary foraminifera of the Qatar Peninsula*, p. 43, pl. 1, figs. 1–6.

Rotalia newboldi D'ARCHIAC AND HAIME, 1853 (part), *Description des animaux fossiles du groupe Nummulitique de l'Inde*, p. 347, pl. 36, fig. 17a–c (not fig. 17d).

Dictyoconoides newboldi (d'Archiac and Haime). – DAVIES, 1927, Geol. Soc. London, Quart. Jour., vol. 83, p. 279, pl. 22, figs. 1–4. – NUTTALL AND BRIGHTON, 1931, India, Geol. Survey, Rec., vol. 65, p. 57, pl. 4, fig. 1.

Lockhartia newboldi (d'Archiac and Haime). – DAVIES, 1932, Roy. Soc. Edinburgh, Trans., vol. 57, pt. 2, no. 13, p. 408.

Test trochoid, moderately large, in apertural view hemispherical with a slightly convex base and a more strongly convex ventral surface; periphery subacute, with a marginal thickening but lacking a marginal canal system; spiral suture clearly visible dorsally, in large forms exhibiting a spiral series of connected elongate tubercles, and in small forms a spiral of thickened porcellanous shell material; ventral surface of larger forms provided with a large knob-like central area which bears a peculiar, cribriform, anastomosing mass of shell material composed of the fused ends of the pillars; wall thick, finely perforate; outer wall exhibiting in thin section the radially fibrous structure of the calcite; chambers visible only on the smooth area of the periphery; fourteen chambers in the final volution, increasing in size as added; septa double, slightly curved; thick, relatively long pillars fan outward from the cortical area toward the ventral surface; final chamber in all specimens too poorly preserved to show the external characteristics of the aperture. Diameter 0.75 mm. to 1.20 mm.; thickness 0.63 mm. to 0.79 mm.

The specimens in the lower portion of the Oldsmar limestone closely resemble those figured by Davies (1932, pp. 416–418) from his study of Lamarck's original types. If the largest of the specimens were considered alone, there would exist little doubt that every one of the Florida specimens were identical with those described by Lamarck. However, when large numbers of specimens are obtained from one horizon, it is possible to see an evolutionary sequence from larger forms with pronounced ventral convexity to smaller forms that might easily be interpreted as *"Lockhartia" cushmani* (Applin and Jordan, 1950). Dr. A. R. Loeblich of the U. S. National Museum kindly lent the writer the holotype and several autotypes of *"Lockhartia" cushmani*. Comparison of these types with the forms found in this study made it possible to recognize consistent differences between *"Lockhartia" cushmani* and the specimens here referred to *Rotalia trochidiformis*. Small *Rotalia trochidiformis* lack the lobulate character of the periphery displayed in the last few chambers of *"Lockhartia" cushmani*. In *Rotalia trochidiformis* there is no depression of the radial ventral sutures, and the wall is more finely perforate. Most important, the specimens of *"Lockhartia" cushmani* do not exhibit the bulb-like convexity of the ventral surface that is typically developed in *Rotalia trochidiformis*.

Rotalia trochidiformis is extremely abundant in the lowermost portion of the Oldsmar limestone at depths between 1500 and 1510 feet. The highest occurrence of the species in this well is at 1450 feet.

Genus LOCKHARTIA Davies, 1932

Lockhartia gyropapulosa Levin, new species
Plate 3, figures 5–8

Test moderately large, ventrally flat or slightly convex, dorsal side obtusely conical; periphery thin, rounded; dorsal cone making an angle of about 105° but decreasing almost immediately to an angle of about 160°; chambers arranged in a trochoid spire of four or five volutions, surrounding a thick mass of umbilical pillars; approximately twenty chambers in the final volution, increasing slightly in size as added; septa obscure except in sections, but can occasionally be seen on the outer rim of the dorsal surface as oblique radial lines; wall thick, perforate, composed of radially fibrous calcite; the terminations of the pillars on the ventral side give the umbilical area a papulose appearance; dorsal side ornamented by four or five centrally located, closely crowded apical pustules, followed immediately by a spiral of pustules diminishing in size toward the periphery, where the test becomes relatively smooth. Diameter 0.925 mm. to 1.00 mm.; thickness 0.592 mm. to 0.625 mm. Axial sections clearly show the arrangement of reniform chambers around the wide central cone of pillars.

This species shows many general similarities to species of *Lockhartia* from the Qatar Peninsula of Arabia. The description of *Lockhartia hunti* var. *pustulosa* Smout (1954, p. 54), from the Lower Eocene of the Qatar Peninsula, distinctly suggests relationship to the Florida species. *Lockhartia gyropapulosa* differs in showing a greater variation in the size of the dorsal pustules, and in having a larger number of chambers, a thinner, more discoidal marginal area, and a flatter ventral surface. The species is found abundantly in the interval between 1490 and 1510 feet.

Lockhartia praealta Levin, new species
Plate 3, figures 9–11

Test moderately large; ventral surface almost flat, dorsal surface a high cone with a rounded terminal area; height slightly greater than the diameter at the base of the ventral surface; chambers arranged in a high, trochoid spire of four or five volutions, increasing in size as added; sutures not visible externally; wall thick, calcareous, composed of radially fibrous calcite; dorsal side ornamented by three or four centrally located pustules which spiral downward and around the test toward the base; wall slightly depressed between the volutions of the strongly raised spiral suture. Average height 0.750 mm.; average diameter 0.700 mm.

Axial sections reveal very large, rectangular to rhomboidal chambers; the umbilical area shows good development of pillars; the pillars arise within a wedge-shaped mass of shell material, extend from the level of the antepenultimate volution diagonally across the interior of the test, and terminate at its thickest portion just below the lower plane of the base.

This species differs from *Lockhartia altispira* Smout, described from the Paleocene of Qatar, in its smaller size and the distinctive orientation of the pillars. *Lockhartia praealta* has its maximum occurrence in the C. E. Robinson well at 1490 feet.

Genus SIPHONINA Reuss, 1850

Siphonina wilcoxensis Cushman

Siphonina wilcoxensis CUSHMAN, 1927, U. S. Nat. Mus., Proc., vol. 72, art. 20, p. 3, pl. 2, figs. 1–3. – CUSHMAN AND PONTON, 1932, Cushman Lab. Foram. Res., Contr., vol. 8, p. 70, pl. 9, fig. 7a–c. – CUSHMAN AND GARRETT, 1939, Cushman Lab. Foram. Res., Contr., vol. 15, p. 86, pl. 15, figs. 7–9. – ISRAELSKY, 1939, Sixth Pacific Sci. Congr., Proc., p. 578, pl. 7, fig. 3. – TOULMIN, 1941, Jour. Pal., vol. 15, p. 605, pl. 18, figs. 15–16. – CUSHMAN, 1944, Cushman Lab. Foram. Res., Contr., vol. 20, p. 27, pl. 7, fig. 27. – CUSHMAN, 1944, Amer. Jour. Sci., vol. 242, p. 14, pl. 2, figs. 3–4. – SHIFFLETT, 1948, Maryland, Dept. Geol., Mines and Water Resources, Bull., no. 3, p. 68, pl. 4, fig. 8.

Siphonina wilcoxensis occurs rarely between 1350 and 1380 feet.

Family AMPHISTEGINIDAE

Genus ASTERIGERINA d'Orbigny, 1839

Asterigerina primaria Plummer var. heligma Levin, new variety
Plate 4, figures 1–2

Test trochoid, circular; flat ventrally, strongly convex dorsally; periphery with a thin, faintly serrate keel which coils upward on the dorsal surface to become a raised spiral suture; two and one-half whorls present in adult specimens; chambers longer than wide, seven or eight in the final volution, slightly inflated ventrally; sutures on dorsal surface elevated and sharply curved toward the posterior, giving a pin-wheel effect; ventral side with a shallow, finely papillose umbilicus and with slightly depressed sutures; wall calcareous, coarsely perforate; aperture an irregular opening extending along the inner edge of the last-formed chamber. Diameter 0.40 to 0.45 mm.; thickness 0.17 to 0.18 mm.

The variety differs from *Asterigerina primaria*, described from the Midway of Texas, in its larger size, greater number of chambers, and less strongly arched aperture. Seven specimens of the new variety were recovered from the interval between 1400 and 1410 feet.

Asterigerina texana (Stadnichenko)
Plate 4, figures 3–4

Eponides texana STADNICHENKO, 1927, Jour. Pal., vol. 1, p. 232, pl. 38, figs. 1–5.
Asterigerina texana (Stadnichenko). – CUSHMAN AND THOMAS, 1929, Jour. Pal., vol. 3, p. 181, pl. 24, fig. 5a–c. – BANDY, 1949, Bull. Amer. Pal., vol. 32, no. 131, pl. 22, fig. 3a–c.
Asterigerina lisbonensis CUSHMAN AND TODD, 1945, Cushman Lab. Foram. Res., Contr., vol. 21, pt. 1, p. 19, pl. 4, figs. 15–18.

The specimens from the Oldsmar limestone are slightly smaller, but otherwise bear a close resemblance to all previous descriptions of the species. Minute forms are often difficult to identify because the papillae tend to obscure the suture pattern. These small forms can be readily recognized, however, by the prominent ventral umbo and the limbate dorsal spiral suture. The species is an abundant constituent of the Oldsmar fauna, occurring between 1250 and 1400 feet. Over 160 specimens were recovered at a depth of 1330 feet.

Genus HELICOSTEGINA Barker and Grimsdale, 1936

Helicostegina gyralis Barker and Grimsdale
Plate 4, figures 5–7, 10–11

Helicostegina gyralis BARKER AND GRIMSDALE, 1936, Jour. Pal., vol. 10, pp. 236–237, pl. 30, figs. 3–5; pl. 32, figs. 4–5; pl. 34, figs. 2–6; pl. 37, fig. 6. – COLE, 1942, Florida, Geol. Survey, Bull., no. 20, p. 34, pl. 15, figs. 4–6; pl. 16, fig. 10. – COLE AND GRAVELL, 1952, Jour. Pal., vol. 26, p. 713, pl. 92, figs. 11–12.

Barker and Grimsdale (1936, p. 244) believed that *Amphistegina lopeztrigoi* was the ancestor of *Helicostegina gyralis*, and that evolution progressed from *Amphistegina lopeztrigoi* through *Helicostegina gyralis* to *Helicostegina dimorpha*. They further believed that this sequence is manifested by a continual increase in the development of subsidiary chambers. The Oldsmar specimens seem to support this evolutionary sequence. At the well locality, the specimens of *Amphistegina lopeztrigoi* do not possess subsidiary chamberlets. This criterion could therefore be used in distinguishing *Helicostegina gyralis* from *Amphistegina lopeztrigoi*.

When it is difficult to determine the presence or absence of secondary chambers in some of the thicker-walled forms, the ventral sides of the specimens can be treated with a weak solution of hydrochloric acid to render the structure more apparent. The more time-consuming process of preparing thin sections is thus avoided.

Helicostegina gyralis occurs abundantly at depths between 1250 and 1390 feet. The greatest concentration of specimens was encountered between 1360 and 1370 feet.

Genus AMPHISTEGINA d'Orbigny, 1826

Amphistegina lopeztrigoi Palmer
Plate 4, figures 8–9, 13–14

Amphistegina lopeztrigoi PALMER, 1934, Soc. Cubana Hist. Nat., Mem., vol. 8, no. 4, p. 255, pl. 15, figs. 6-8. – BARKER AND GRIMSDALE, 1936, Jour. Pal., vol. 10, p. 233, pl. 30, figs. 1-2; pl. 32, fig. 1; pl. 38, fig. 3. – COLE, 1942, Florida, Geol. Survey, Bull., no. 20, pp. 33-34, pl. 15, figs. 2-3; pl. 16, fig. 11; 1944, ibid., no. 26, p. 55, pl. 1, fig. 17; pl. 8, fig. 16; pl. 9, figs. 10–13. – COLE AND GRAVELL, 1952, Jour. Pal., vol. 26, no. 5, p. 714, pl. 91, figs. 6, 8.
Amphistegina senni CUSHMAN, 1945, in VAUGHAN, Geol. Soc. Amer., Mem., no. 9, pt. 1, p. 49, pl. 19, figs. 1–4.

In limestone well cuttings, *Amphistegina lopeztrigoi* is easily confused with the related form *Helicostegina gy-*

ralis. This is especially true because in *Helicolepidina gyralis* the thin outer marginal area which bears the secondary chamberlets is usually destroyed by erosion. In thin sections, however, *Helicolepidina gyralis* shows a smaller number of whorls than *Amphistegina lopeztrigoi*, and the whorls are more widely spaced. For example, *Helicolepidina gyralis* most commonly has two and one-half to three whorls, whereas *Amphistegina lopeztrigoi* has three to three and one-half whorls and a wider spacing of septa. The second chamber is usually distinctly smaller and less spherical than the proloculum.

For rapid separation without thin sectioning, the following characteristics can be used if care be taken to consider only those features not resulting from dimorphism:

Amphistegina lopeztrigoi	*Helicostegina gyralis*
Test stoutly and unevenly inflated.	Test lenticular, relatively thin.
Cord-like peripheral band usually present.	Flange-like, acute peripheral area.
Wall thick, structure visible only on eroded forms.	Wall delicate, subsidiary chambers visible on wet surface.
Pustules do not closely follow the suture pattern.	Pustules occur on, and follow the radial outlines of the sutures.

Helicostegina gyralis occurs abundantly in the upper portion of the Oldsmar limestone at depths between 1250 and about 1380 feet.

Family ANOMALINIDAE

Genus CIBICIDES Montfort, 1808

Cibicides sassei Cole

Cibicides sassei COLE, 1927, Bull. Amer. Pal., vol. 14, no. 51, p. 35, pl. 4, figs. 10–11. – CUSHMAN AND THOMAS, 1929, Jour. Pal., vol. 3, no. 2, pp. 182, 184. – CUSHMAN AND THOMAS, 1930, Jour. Pal., vol. 4, no. 1, pl. 4, fig. 4a–c. – CUSHMAN AND DUSENBURY, 1934, Cushman Lab. Foram. Res., Contr., vol. 10, p. 64, pl. 9, fig. 5a–c. – HOWE, 1939, Louisiana, Dept. Cons., Geol. Bull., no. 14, pl. 13, figs. 18–19. – CUSHMAN AND APPLIN, 1943, Cushman Lab. Foram. Res., Contr., vol. 19, p. 46, pl. 8, fig. 12. – CUSHMAN AND TODD, 1945, Cushman Lab. Foram. Res., Contr., vol. 21, p. 20. – BANDY, 1949, Bull. Amer. Pal., vol. 32, no. 131, pl. 20, fig. 4a–c.

Scattered specimens of *Cibicides sassei* occur in the cuttings at 1250 and at 1400 feet.

Family DISCOCYCLINIDAE

Genus PSEUDOPHRAGMINA H. Douvillé, 1923

Pseudophragmina (Proporocyclina) cedarkeysensis Cole
Plate 4, figure 12

Pseudophragmina (Proporocyclina) zaragosensis (Vaughan). – COLE, 1942, Florida, Geol. Survey, Bull., no. 20, pp. 46–48, pl. 13, figs. 1–5; pl. 14, figs. 1–5.

Pseudophragmina (Proporocyclina) cedarkeysensis COLE, 1944, Florida, Geol. Survey, Bull., no. 26, pp. 81–83, pl. 2, fig. 13; pl. 18, fig. 9; pl. 26, figs. 1–4; pl. 27, figs. 1–2. – COLE AND BERMUDEZ, 1947, Bull. Amer. Pal., vol. 31, no. 125, p. 17, pl. 7, figs. 6–7.

Discocyclina (Discocyclina) blanpiedi Vaughan. – COLE, 1944, Florida, Geol. Survey, Bull., no. 26, p. 75, pl. 3, fig. 3; pl. 6, fig. 19; pl. 26, fig. 8; pl. 27, fig. 4; pl. 28, figs. 3–5.

The majority of the specimens obtained from the well cuttings were broken, so that the periphery was rarely preserved. Often, the specimens were split sagittally, and rapid determinations could therefore be made without thin sectioning. These forms from the Oldsmar most closely resemble those described by Cole (1944, p. 82) from a well in Levy County, Florida, at a depth of 1470 feet. The species is moderately abundant only in the interval between 1300 and 1310 feet.

Phylum ARTHROPODA

Order OSTRACODA

Suborder PLATYCOPA

Family CYTHERIDAE

Subfamily CYTHERIDEINAE

Genus AULOCYTHERIDEA Howe, 1951

Aulocytheridea margodentata Howe

Aulocytheridea margodentata HOWE, 1951, Florida, Geol. Survey, Bull., no. 34, pt. 1, pp. 7–8, pl. 2, figs. 11–16.

A single right valve represents the only recovery of *Aulocytheridea margodentata* in the Robinson well. Except for the destruction of the marginal spines, the valve is in good condition. Because of its small size and the absence of nodes, the specimen may represent an early molt. It was found in the interval between 1330 and 1340 feet.

Genus HAPLOCYTHERIDEA Stephenson, 1936

Haplocytheridea cf. goochi (Stephenson)

Cytheridea (Haplocytheridea) goochi STEPHENSON, 1942, Jour. Pal., vol. 16, no. 1, p. 106, pl. 18, figs. 9–10.

Haplocytheridea goochi (Stephenson). – BLAKE, 1950, Jour. Pal., vol. 24, no. 2, p. 176, pl. 29, figs. 17–18.

Haplocytheridea goochi is a common fossil in beds of Claiborne age. Since only one specimen was found in the Robinson well cuttings, it is safe to assume that it represents contamination.

Subfamily XESTOLEBERINAE

Genus XESTOLEBERIS Sars, 1865

Xestoleberis sp.

Seven specimens of *Xestoleberis* were recovered from the well cuttings. All of these have tightly cemented valves.

It was thus impossible to observe internal features. On the basis of the external characteristics, the specimens most closely resemble *Xestoleberis* sp. figured by Blake (1950, pl. 29, fig.8). They were found in the interval between 1400 and 1410 feet.

Family TRACHYLEBERIDAE

Genus CYTHEREIS Jones, 1849

Cythereis? longicostata Blake

Cythereis? longicostata BLAKE, 1950, Jour. Pal., vol. 24, no. 2, p. 178, pl. 29, figs. 20–21.

Cythereis? longicostata is represented in the well cuttings by one specimen, a contamination, from the interval between 1250 and 1260 feet.

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EXPLANATION OF PLATES

PLATE 1

1 *Valvulina* sp., × 25.
2–3 *Coskinolina elongata* Cole
     2, side view; 3, ventral view of eroded specimen; both × 31.
4–6 *Nummulites* sp.
     4–5, side views of a single specimen; 6, sagittal section under crossed nicols; all × 43.
7–10 *Nonion mimica* Levin, n. sp.
     7–9, side and apertural views of the holotype; 10, apertural view of metatype with completely developed final chamber; all × 55.

PLATE 1 *(continued)*

11–12 *Quinqueloculina akneriana* d'Orbigny
Lateral views, × 51.
13–14 *Miscellanea nassauensis* Applin and Jordan var. *reticulosus* Applin and Jordan
Side and apertural views, × 57.
15–17 *Discorbis yeguaensis* Weinzierl and Applin
Dorsal, apertural, and ventral views, × 80.

PLATE 2

1–2 *Miscellanea nassauensis* Applin and Jordan
Side and apertural views, × 45.
3–4 *Borelis floridanus* Cole
Side and apertural views, × 42.
5–8 *Tubulogenerina turbina* Levin, n. sp.
5, side view; 6, apertural view; 7, sagittal section through a chamber, showing central core of shell material; 8, axial section; all × 47.
9–11 *Discorbis inornatus* Cole
9, peripheral view; 10, dorsal view; 11, ventral view; all × 95.
12–14 *Gyroidina lottensis* Garrett
12, ventral view; 13, apertural view; 14, dorsal view; all × 90.
15–16 *Discorbis tallahattensis* Bandy
15, ventral view; 16, dorsal view; both × 176.
17–19 *Gyroidina lottensis* Garrett var. *impensa* Levin, n. var.
17, ventral view; 18, apertural view; 19, dorsal view; all × 46.
20–22 *Eponides oldsmarensis* Levin, n. sp.
20, ventral view; 21, apertural view; 22, dorsal view; all × 51.

PLATE 3

1–4 *Rotalia trochidiformis* (Lamarck)
1–3, dorsal, apertural, and ventral views, × 55; 4, sagittal section, × 30.
5–8 *Lockhartia gyropapulosa* Levin, n. sp.
5, sagittal section cut near the base, × 30; 6–8, dorsal, peripheral, and ventral views of a single specimen, × 38.
9–11 *Lockhartia praealta* Levin, n. sp.
9, axial section, × 30; 10, dorsal view, × 40; 11, side view of specimen with portion of wall broken, × 40.

PLATE 4

1–2 *Asterigerina primaria* Plummer var. *heligma* Levin, n. var.
1, dorsal view; 2, ventral view; both × 56.
3–4 *Asterigerina texana* (Stadnichenko)
3, ventral view; 4, dorsal view; both × 62.
5–7 *Helicostegina gyralis* Barker and Grimsdale
5–6, side and peripheral views of a single specimen; 7, side view of an acid-treated specimen, showing the development of secondary chambers; all × 29.
8–9 *Amphistegina lopeztrigoi* Palmer
Peripheral and side views of a typical specimen, × 56.
10–11 *Helicostegina gyralis* Barker and Grimsdale
10, sagittal section; 11, axial section; both × 23.
12 *Pseudophragmina (Proporocyclina) cedarkeysensis* Cole
Split specimen showing chamber arrangement, × 45.
13–14 *Amphistegina lopeztrigoi* Palmer
Sagittal and axial sections, × 24.

PLATE 2
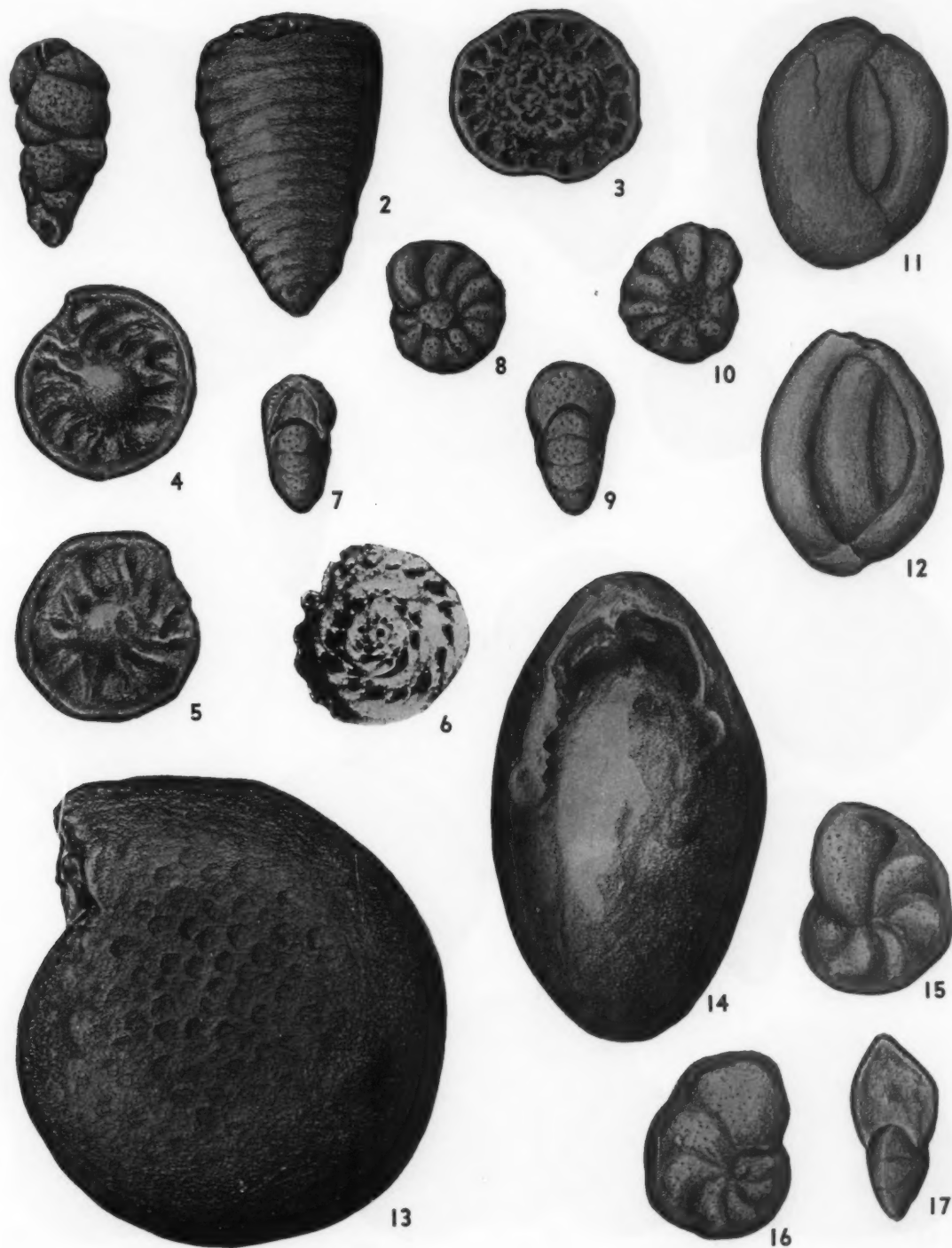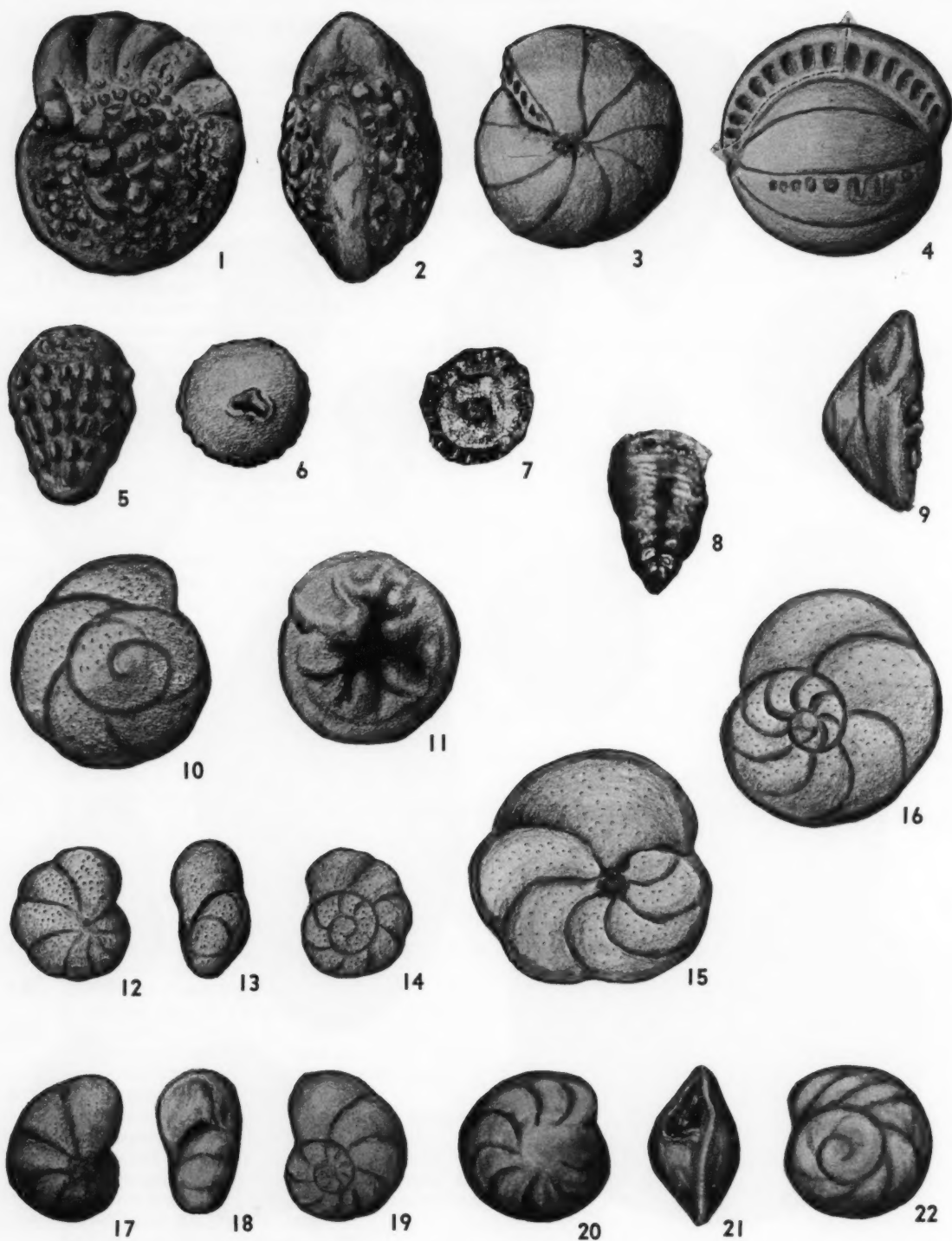
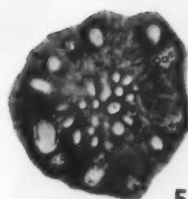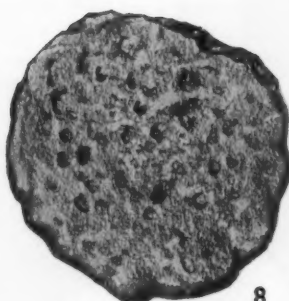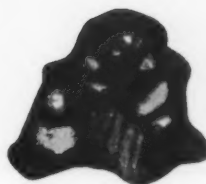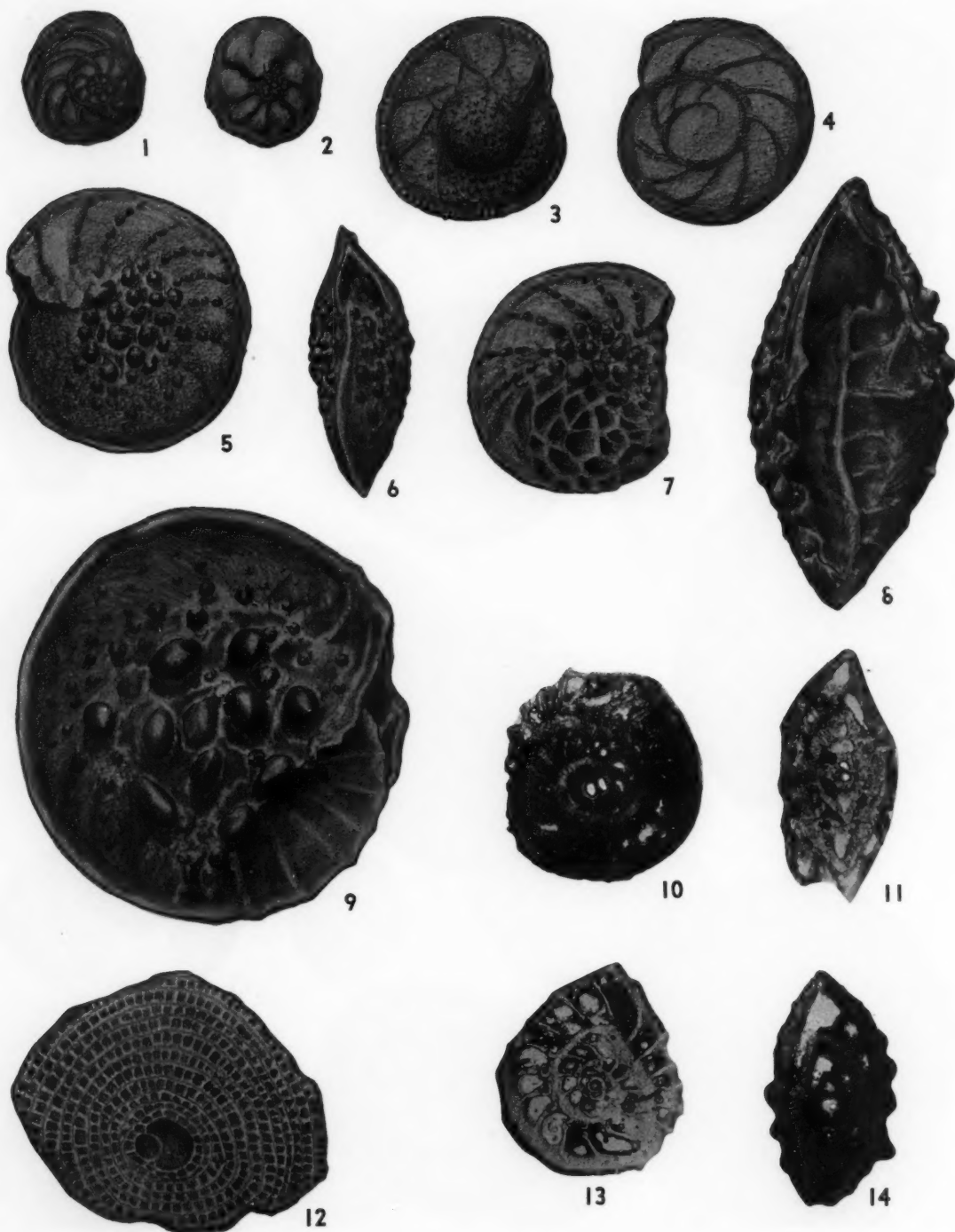ABSTRACT: *Three species of the genus* Sherbornina *Chapman, 1922, are of stratigraphic value in the Lower Tertiary of southeastern Australia. The type species,* Sherbornina atkinsoni *Chapman, is emended, and two new species are described. The structure of the earlier species suggests that the genus is related to the Elphidiidae. The stratigraphic distribution is discussed. The known range of the genus is from Upper Eocene to Lower Miocene.*

The foraminiferal genus Sherbornina in southeastern Australia

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INTRODUCTION

The genus *Sherbornina* Chapman, 1922, was mono-typic, based on *Sherbornina atkinsoni* Chapman, from the Oligocene at Table Cape, Wynyard, Tasmania. Discovery of the holotype in the private collection of the late Frederick Chapman has confirmed the suspicion that the type description was not entirely correct, and the species is here redescribed. The basic work of redescription was done by Carter, and the two new species were described by Wade, who also investigated the relationships of the genus. The three species have restricted stratigraphic ranges, and the two younger, at least, have a widespread distribution in South Australia and Victoria. The oldest, *Sherbornina crassata*, n. sp., is at present known only from the Upper Eocene in South Australia. *Sherbornina atkinsoni* first appears in the Oligocene, and its upper range overlaps that of *Sherbornina cuneimarginata*, n. sp., which extends from the Upper Oligocene to the Lower Miocene.

SYSTEMATIC DESCRIPTIONS

The letters "N.M.V." refer to specimens deposited in the National Museum of Victoria, Melbourne, Victoria; "G.S.M.V." refers to those deposited in the Museum of the Geological Survey of Victoria, Melbourne; and "A.U.G.D." refers to those deposited in the Palaeontological Collection of the University of Adelaide, South Australia.

Family ELPHIDIIDAE Galloway, 1933

#### Genus **Sherbornina** Chapman, 1922
Text-figure 1

Sherbornina CHAPMAN, 1922, Linnean Soc. London, Jour., Zool., vol. 34, no. 230, pp. 501–503.

The tests are discoidal, with radiate calcareous walls. The chamber arrangement is planar or almost so, but with the dorsal and ventral sides differentiated (pseudoplanispiral). The degree of asymmetry is variable. In the earlier species some individuals are almost symmetrical, while in the youngest species the adult shows totally different structures on the dorsal and ventral sides. In both megalospheric and microspheric forms there is an early coil, roughly planispiral. It is usually differentiated in the megalospheric form, the protoconch being followed by one or two globular chambers. These comprise the early nepionic stage. The last of these chambers has more than one foraminal pore; the later chambers are longer than wide, increasing gradually in relative length (pl. 3). These comprise the late nepionic stage. In the microspheric form a small protoconch is followed by a number of chambers increasing gradually in length relative to width. The nepionic stage is not differentiated into "early" and "late." In both forms there is a row of foraminal pores in the plane of growth. In the neanic growth-stage the chambers increase rapidly in length and become embracing, then annular. No aperture is known.

Following the globular chambers, the dorsal and ventral surfaces of the chambers become corrugated, most strongly near the sutures, the corrugations dying out over the rounded margin. They alternate from chamber to chamber. The ridges of one chamber overlap the downfolds of the preceding one, with prolongations of the chamber lumina below them. This may continue throughout growth, or the ventral side may be further differentiated by the enlargement of the prolongations. As each chamber is added, a more-or-less complete layer of shelly material is laid over the whole test (text-fig. 1). The layering is not as thick in the later species as in the earliest one. Except near the sutures, where there is a septal flap, the septum is single in the adult. A dorsoventrally symmetrical canal system of spiral and septal canals in the juvenile, and of septal and radial canals in the adult, is present. Branches open on the surface of the test as coarse pores. The last pair of an-
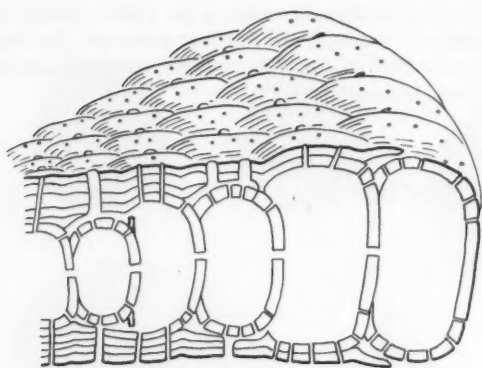
TEXT-FIGURE 1

Block diagram of *Sherbornina* based on *Sherbornina crassata* Wade, n. sp., and *Sherbornina atkinsoni* Chapman, × ca. 215, showing the widening and constricting of the annular chambers at the ridges and downfolds of the wall; the foraminal pores in the centre of the septal face; the short septal flaps separating the annular canals from the chamber lumina; the annular canals in transverse section merging with the radial canals in longitudinal section; the coarse pores by which the branches from the canals reach the surface; the finer perforations of the chamber walls leading either into the canals or directly to the surface of the test; the layering of the test walls as each chamber is added; and the corrugations of the surface alternating in position from chamber to chamber. For simplicity, irregularities in the later layers of shell material, which often mask the initial corrugations on the earlier parts of the test, have been omitted.
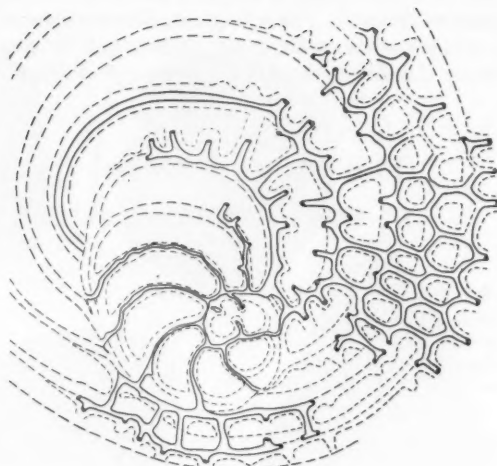
TEXT-FIGURE 2

Diagrammatic drawing of the early whorls of *Sherbornina crassata* Wade, n. sp., from horizontal section A.U.G.D. no. F15286, × ca. 155; the canal system is shown in solid lines, and the outlines of the septa, the septal flaps, and the downfolds of the chamber walls, which enclose the canal system, are shown in dashed lines; the juvenile canal system consists of a spiral canal giving rise to septal canals which send branches to the surface of the test; in the annular adult the spiral canal is replaced by radial canals formed by branches from the septal canals occupying downfolds in the corrugated dorsal and ventral chamber walls; branches from the radial canals reach the surface of the test.

nular canals opens to the exterior by a ring of pores at, or a short distance distally from, the last suture (text-fig. 1). These pores occupy the position that would have been occupied by the next radial canals, with further growth. The perforations of the test wall, which are much finer than the canals, may open into them, or may lead independently to the surface of the test. The apertural face may be imperforate, or the chamber walls may be wholly perforate.

In all three species (*Sherbornina atkinsoni* Chapman, *Sherbornina crassata*, n. sp., and *Sherbornina cuneimarginata*, n. sp.), megalospheric forms are common, microspheric and intermediate forms rare.

Sherbornina crassata Wade, new species
Plate 1, figure 8; plate 2, figures 4–6;
plate 3, figures 4–6; text-figure 2

Test discoidal, up to 2 mm. in diameter and less than 0.4 mm. in thickness. Horizontal walls thick to very thick; surface finely pustulose, showing an irregularly circular arrangement of coarse pores. The centres of one or both sides are usually slightly depressed, but not

symmetrically. As shown in horizontal sections, the megalospheric test commences with two or three globular chambers connected through a small interio-marginal foraminal pore. The second or third chamber develops more than one foramen, and the next two to six chambers are much longer in proportion to width than the first few, but they increase regularly in size. Foraminal pores become numerous. The megalospheric protoconchs have an internal diameter ranging from 0.020 to 0.032 mm. (in seven specimens); the one intermediate specimen has a protoconch of 0.014 mm., and the one microspheric specimen has an internal diameter of approximately 0.007 mm. In the intermediate and microspheric specimens, no change of shape between the first few chambers and those following is found (text-fig. 2; pl. 3, fig. 4). There are eleven chambers in the nepionic portion of the microspheric specimen. At this stage two or three embracing neanic chambers are added, and then cyclic growth is established. The foraminal pores occur in a ring around the middle of each septal face, with an imperforate area on either side. The upper and lower surfaces of the chambers are coarsely perforate.

From an early stage of growth the proximal edges of the chambers show corrugations alternating in position from chamber to chamber and forming small ridges with prolongations of the chamber lumina below them which overlap onto the previous chamber. Between them, downfolds occur whose walls form ribs on the interiors of the chambers. The perforations of the chamber walls pass through both. As each chamber is added its wall encloses the whole test so that the test wall is clearly layered (pl. 2, figs. 5–6). From the initial chamber, throughout growth, a prominent bilaterally symmetrical canal system is present. On each side this consists of a canal encircling the initial chamber, connecting with a spiral canal passing around the spiral suture of the coiled portion. At each septal suture the spiral canal gives off a sinuous septal canal which sends branches from the end of each curve to the surface of the test, through the later layers of shelly material (pl. 3, fig. 4; text-fig. 2). The septal canals cross the thickened spiral lamina, and may join the more sharply angled annular septal canals which are formed with the advent of annular growth. The annular septal canals have branches directed centripetally from the tips of the prolongations, and peripherally from the downfolds. As the prolongations of one chamber overlap the downfolds of the preceding chamber, continuous radial canals are established. Branches lead to the surface of the test (text-fig. 1).

Distribution: Coastal cliffs at Kingscote, Kangaroo Island (type locality), and Moorlands, 65 miles east-southeast of Adelaide, in the lower marine bed; both in South Australia. Both occurrences are Upper Eocene in age.

Depository: Holotype, A.U.G.D. no. F15282. Paratypes, A.U.G.D. no. F15283a–e. Tectotypes, A.U.G.D. nos. F15284 to F15291.

Remarks: About sixty specimens were available, of which twenty were sectioned. Externally *Sherbornina crassata*, n. sp., is almost identical with *Sherbornina atkinsoni* Chapman; however, its thick wall gives it a more compact appearance and a greater thickness for similar diameters. Specimens of *Sherbornina crassata* between 1 and 2 mm. in diameter are mostly between 0.30 and 0.36 mm. in thickness; a few are a little thicker, but none has been found as thick as 0.4 mm. Specimens of *Sherbornina atkinsoni* of a similar diameter measure from 0.20 to 0.26 mm. in thickness. The pores on the surface of *Sherbornina crassata* are more regularly arranged (in rough annuli) than in *Sherbornina atkinsoni*, but this is often hidden by the rough shelly surface. In the young stages, *Sherbornina atkinsoni* averages two more chambers in the late nepionic stage and one more in the neanic stage than *Sherbornina crassata*. This is reflected in the size of the young stages, that of *Sherbornina crassata* averaging only four-fifths that of *Sherbornina atkinsoni*, the maximum diameter of the nepionic portion ranging from 0.078 to 0.110 mm. (in seven horizontal sections of megalospheric individuals), while in *Sherbornina atkinsoni* it ranges from 0.094 to 0.130 mm. (in eleven horizontal sections of megalospheric individuals). In vertical section the much thicker wall of *Sherbornina crassata* is obvious, and the layering is better developed. The canal system is also seen better in the thicker walls.

Sherbornina atkinsoni Chapman
Plate 1, figures 1–5; plate 2, figures 1–3;
plate 3, figures 1–3

Sherbornina atkinsoni Chapman, 1922, Linnean Soc. London, Jour., Zool., vol. 34, no. 230, pp. 501–503, pl. 32, figs. 1–5. Test discoidal, flat to slightly convex dorsally, flat to concave ventrally, up to about 2 mm. in diameter; adults are between 0.2 and 0.26 mm. in thickness. The early part is approximately planispiral. In the megalospheric form it consists of four to ten nepionic chambers, followed by three or four successively more embracing neanic chambers. The one microspheric test sectioned has fourteen nepionic chambers and five neanic chambers, totalling nineteen chambers in the juvenile stages. The internal diameter of the protoconch is 0.004 mm.; those of the megalospheric generation (twelve specimens) range from 0.018 to 0.031 mm.; one intermediate specimen has an internal diameter of 0.014 mm. The proximal edges of the chambers are corrugated, the upward ridges roofing centripetally-directed prolongations of the chamber lumina. The downfolds between the ridges project as thick ribs on the inside of the chamber wall. The corrugations of one chamber usually alternate with those of the preceding chamber. The layering of the chamber walls is often rather incomplete. Well-layered specimens show the fully developed canal system of septal canals with centripetally and peripherally directed branches forming radial canals (pl. 3, fig. 1). Often the branches do not meet, but lead directly to the surface. In specimens with very incomplete layering, the canal openings may be irregular. The surface of the test may become covered by irregular granules of shelly material which obscure the structural features. The walls are subtranslucent and entirely perforate. Their rather coarse perforations are continued through the later layering. The centripetal prolongations of the ventral side are often a little larger than those of the dorsal side. This slight asymmetry is accentuated by the fact that the adult chambers are often added about a gently curved axis, concave ventrally, and not in a plane.

Distribution: Table Cape, Wynyard, Tasmania, in the lower part of the Tertiary section, "the *Crassatellites* Bed" of Chapman (1922) (type locality). The deposit is Oligocene in age (Gill and Banks, 1956, p. 11).

In Victoria, it was found near Torquay, in the Jan Juc formation (Raggatt and Crespin, 1955); it is common at Bells Headland and rare elsewhere. It has also been found at Waurn Ponds, near Geelong (rare); at Maude, in the base of the "upper Maude limestone" (rare); and in the Aire district, where it is common in the Calder River limestone and rare in the "upper Glen Aire clays." All these occurrences are in southwestern Victoria, and aside from that at Maude, which may be Lower Miocene in age, are considered to be of Oligocene age by the

writers, although Raggatt and Crespin (1955) consider the Jan Juc formation of Torquay to be Eocene.

In South Australia, it occurs at Aldinga Bay, south of Adelaide, in the Port Willunga beds, and in a correlated formation in the South Australian Mines Department bore Willunga no. 1, three and a half miles inland, from 168–172 feet down to 366–376 feet; it is common in both formations. In the Adelaide Plains Basin, it was found in the Croydon Bore near Adelaide, at a depth of 1126–1230 feet; 18 miles to the north-northeast, in a bore on C. A. Goldfinch's property 2 miles north of Smithfield; and in other bores south-southwest of Adelaide, recorded by Crespin (1952, 1954). It has also been found on the east coast of Yorke Peninsula, from a point between Sheoak Flat and Surveyor's Point southward to Wool Bay, where it is rather common, and at Moorlands, in the South Australian Mines Department bore no. Y64, at 38–46 feet. The upper part of the range of *Sherbornina atkinsoni* in the Willunga Bore may be of Lower Miocene age, but the remainder of the occurrences are considered Oligocene.

Depositories: Chapman's holotype, paratype, and figured vertical section of *Sherbornina atkinsoni* were formerly in his personal collection. They are now in the collections of the National Museum of Victoria, nos. P.17163 (holotype), P.17164 (paratype), P.17165 (tectotype), and P.17166, a perfect horizontal section with the same preservation but no label (pl. 1, figs. 1–4). Additional material is deposited in the Museum of the Geological Survey of Victoria, Melbourne.

Remarks: Study of the type material and of topotype material kindly supplied by M. R. Banks leaves no doubt that *Sherbornina atkinsoni* has been correctly identified in Victoria and South Australia. Its structure, however, is not in agreement with Chapman's original description. Chapman interpreted the semicircular markings visible on the dorsal and ventral surfaces of the chambers as spatulate lateral chambers. The grinding of many tests has shown that these markings are due to the thickening of the chamber walls in the downfolds between the ridges, in many cases accentuated by the canal system following the downfolds. The spaces they appear to encircle in thin section are invariably the prolongations of the chamber lumina extending under the ridges. Specimens of *Sherbornina atkinsoni* which have the canal system well developed can be distinguished from *Sherbornina crassata* by their thinness and often by their greater number of juvenile chambers. In others, spaces trapped rather irregularly in the test wall by the addition of incomplete layers are equivalent to the canal system. They are not lateral chambers, nor do they correspond to Chapman's "lateral chambers" in horizontal section; they do correspond with his "lateral chambers" in vertical section, as can be seen by his tectotype (pl. 1, fig. 3; Chapman, 1922, fig. 3). Occasionally the ribs of the chamber wall, which project into the lumen below the downfolds, are cut by horizontal sections below the depth reached by most of them; these

appear to be the "septa" which Chapman described in the annular ("median") chambers.

Sherbornina cuneimarginata Wade, new species
Plate 1, figures 6–7; plate 2, figures 7–11;
plate 3, figures 7–10

The tests range up to about 1 mm. in diameter and 0.25 mm. in thickness. They are discoidal, the dorsal side flat and the ventral conical around the periphery and very deeply depressed in the centre. In edge view the margin of the test is therefore wedge-shaped. The early part is almost planispirally coiled. The early nepionic stage consists of two or three globular chambers, the late nepionic of two to four narrow chambers increasing rapidly in length but not appreciably in width, followed by two or three neanic embracing chambers; the chambers then become annular (pl. 2, fig. 7; pl. 3, figs. 9–10). On the dorsal side the wall of each chamber is corrugated strongly near the proximal edge, the corrugations dying out at the rounded periphery. Those of each chamber alternate with those of the chamber before, and as a result the tip of each ridge is extended over the corresponding depression of the chamber before, almost but not quite covering it; rings of pits are left, giving the appearance of differing ornamentation on the last chamber and the remainder of the test (pl. 1, fig. 6a). Vertical sections (pl. 2, figs. 8–11) show that prolongations of the chamber lumen occur below the ridges. They lead into a well developed canal system which opens into the pits on the surface.

Juvenile specimens show that the ridges of the early chambers of the ventral side become elongate, centripetally directed prolongations by the time annular growth is established or even sooner. As the test increases in size, the prolongations become larger but do not increase in relative length, so that the later rings of prolongations do not cover the inner ends of the early ones. They form the wall of the central hollow, which is floored by the single layer of chambers of the coiled juvenile stage (pl. 2, figs. 8–11). The walls are translucent, entirely perforate, and the perforations penetrate later material added to the walls. Cross-sections (pl. 3, fig. 8) show that the partitions between neighbouring ventral prolongations are double, formed by a fold of the chamber wall, but sometimes the fold is not deep enough to reach the previous chamber at the inner end, and two or more prolongations are fused.

As the ventral prolongations are much larger than the dorsal ones, they are fewer in number. The ventral canal system is strongly modified in the adult. It gives rise to at least part of a stolon system which connects the lumina of the ventral prolongations, but some of these stolons may be perforations of the walls. The floor of the ventral depression is usually covered with shelly material which is laid over earlier chambers as later ones are added, but characteristically this species does not add well developed layers to the test wall. On the dorsal side the layers of shelly material rarely reach across the whole surface, but usually thin out before

the central part is reached, leaving its walls slightly thickened in a shallow residual depression formed by the addition of layers of material to the walls farther out. Toward the periphery the walls again become thin, as they consist of fewer and fewer layers.

Distribution: In Victoria, it has been found in the Torquay district, in a quarry on the east bank of Spring Creek, about one-quarter mile north of the bridge on the Torquay-Anglesea road, in an inland extension of the Puebla formation (Raggatt and Crespin, 1955), the "Scutellina Limestone" (Pritchard, 1923); common (type locality). It also occurs in the Torquay coastal sections, in the Puebla formation (rare); in the Aire district, at Castle Cove, Carter sample CC52 (rare); at Batesford, in the floor of a railway cutting at the bottom of the "New Quarry" of Australian Cement Ltd. (rare); at Maude, at the base of the "upper Maude limestone" (rare); and in the Longford district, Gippsland, in a quarry in Allotment 36, Parish of Glencoe (rare); and in McColl's and Robinson's quarries, Parish of Glencoe (Kenny, 1941) (rare).

In South Australia, it occurs in the South Australian Mines Department bore Willunga no. 1, on the road adjacent to Section 222/3 and 232/3, Hundred of Willunga, at 125–246 feet (common); at 307–312 feet one specimen with a preservation that does not suggest contamination was found. It has also been found in the River Murray cliffs at Blanchetown, just below a horizon with plentiful specimens of Lower Miocene *Lepidocyclina* and extending downward at least 50 feet but still in Lower Miocene deposits (rare). All the occurrences are of mid-Tertiary age.

Depositories: Holotype, G.S.M.V. no. 54426. Paratypes, G.S.M.V. nos. 54427 and 54428, and A.U.G.D. nos. F15111 to F15114. Tectotypes, G.S.M.V. no. 54429, and A.U.G.D. nos. F15115 to F15119.

Remarks: About 300 specimens of *Sherbornina cuneimarginata*, n. sp., were available for examination. As the vertical sections show (pl. 3, figs. 8–11), there is a considerable variation in thickness, due mainly to the development of the ventral side. Growth stages from small, coiled juveniles to adult are represented. The maximum diameter of the nepionic stage varies from 0.054 to 0.080 mm., as against 0.094 to 0.130 mm. in *Sherbornina atkinsoni*. On the average, nepionic *Sherbornina cuneimarginata* is little more than half the maximum diameter of nepionic *Sherbornina atkinsoni*. Like *Sherbornina crassata*, it averages two fewer nepionic chambers and one fewer neanic chamber than *Sherbornina atkinsoni*. Late in the juvenile stage the ventral prolongations become more prominent. The great development of the ventral prolongations of adult *Sherbornina cuneimarginata* causes it to be unlike *Sherbornina atkinsoni* in ventral and side view. In dorsal view only the small size of the initial spiral distinguishes it from specimens of *Sherbornina atkinsoni* with a regular ornamentation. The great thickening which masks the original surface

of the walls of *Sherbornina crassata* prevents a close similarity between its dorsal surface and that of *Sherbornina cuneimarginata*.

SYSTEMATIC POSITION OF SHERBORNINA

The close approach to planispiral coiling in the early part of the test, as in later stages, indicates that this character is probably to be found among its relatives. The canal system is best developed in *Sherbornina crassata*, n. sp., locally the oldest species, where it originates as early as the initial chamber. A similar canal system with spiral canals giving rise to septal canals with branches to the surface of the test is found in *Elphidium*, another calcareous radiate genus. The "prolongations" of the chamber lumina in *Sherbornina* differ from the "retral processes" of *Elphidium* only in being in open communication with the canal system. The layering of the test wall is another character found in the Elphidiidae. It is therefore suggested that *Sherbornina* belongs in the Elphidiidae, possibly close to *Elphidium*.

Chapman (1922) separated *Sherbornina* from *Cycloloculina* Heron-Allen and Earland only on the ground that *Sherbornina atkinsoni* has lateral chambers. *Cycloloculina eocenica* (Terquem), from the base of the lower Lutetian at Grignon, was the only species available for comparison. From the literature, it appears to be a characteristic species of *Cycloloculina*. It has very deeply depressed sutures which are bridged over by the proximal ends of the ridges occurring on the surface of the later juvenile coiled stage and on the adult. The deep bridged depressions between the chambers occupy the same position as the septal canals of *Sherbornina*, but even if they are regarded as an incipient canal system, there is a vast difference between it and the complex canal system of *Sherbornina*. There is also very little thickening of the test wall. In spite of their similar growth-forms, it seems that *Cycloloculina eocenica* and *Sherbornina* are generically distinct. A study of the type species of *Cycloloculina*, *Cycloloculina annulata* Heron-Allen and Earland, is needed to evaluate the position of this genus, which might also belong in the Elphidiidae, but it is not likely to disprove the generic distinction between *Sherbornina* and *Cycloloculina*.

STRATIGRAPHIC POSITION OF SHERBORNINA

At Kingscote, South Australia, *Sherbornina crassata* occurs with an Upper Eocene fauna which includes *Crespinella* sp., *Linderina* sp., and *Crespinina kingscotensis* Wade. A similar fauna occurs at Moorlands, in bores in the lower part of the marine Tertiary beds. At less depth, *Sherbornina atkinsoni* is found in

PLATE 1
All figures unretouched.

1–5 *Sherbornina atkinsoni* Chapman
> 1, holotype, N.M.V. no. P.17163, × 32: a, dorsal view, flat; b, edge view; c, ventral view, concave; 2, paratype, N.M.V. no. P.17164, × 32: a, dorsal view, showing alternation of corrugations from chamber to chamber; b, ventral view, concave; 3, tectotype, N.M.V. no. P.17165, × 58; 4, horizontal section, N.M.V. no. P.17166, × 58; cracks in clay filling make apparent partitions in outer chambers at lower right; 5, specimen split on median plane, G.S.M.V. no. 54425, × 70, showing ribs formed inside chambers by downfolds in outer walls, and prolongations of chamber lumina underlying external ridges.

6–7 *Sherbornina cuneimarginata* Wade, n. sp.
> 6, paratype, A.U.G.D. no. F15111, × 32: a, dorsal view, showing corrugations on last chamber and rows of pits on earlier chambers; b, edge view; c, ventral view, showing large prolongations and central depression; 7, holotype, G.S.M.V. no. 54426, × 32: a, dorsal view; b, edge view; c, ventral view.

8 *Sherbornina crassata* Wade, n. sp.
> Holotype, A.U.G.D. no. F15282, × 32: a, dorsal view; b, edge view, showing great thickness of test as compared with *Sherbornina atkinsoni*; c, ventral view; small bryozoan adhering to test on right side of specimen; strong recrystallization masks detail of test.

PLATE 2
All figures unretouched; fig. 2 b–c × 160, others × ca. 100; figs. 2a, 3 and 5 are composite.

1–3 *Sherbornina atkinsoni* Chapman
> 1, megalospheric specimen, G.S.M.V. no. 54422, showing three early and five late nepionic chambers, two neanic chambers, and numerous foraminal pores in septa; 2a–c, vertical section, G.S.M.V. no. 54419, showing layered walls enclosing annular and radial canals and penetrated by pores arising from canals and from chamber lumina; short septal flaps separate annular canals from lumina except where additional pores penetrate them; foraminal pores lie in middle of septa; fig. 2c shows pore between chamber lumen and annular septal canal at top of right-hand chamber and of second chamber from right, infilled with black material in each; in fig. 2b, left-hand chamber at bottom is sectioned at side of pore, and shows a re-entrant angle at junction of septal flap and outer wall of chamber, inside an external ridge; 3, vertical section, G.S.M.V. no. 54420.

4–6 *Sherbornina crassata* Wade, n. sp.
> 4, megalospheric horizontal section, A.U.G.D. no. F15288, showing two early and three late nepionic chambers, and three neanic chambers; annular canals visible in lower part of section, each bounded by septal face on proximal side and by arcuate curves of septal flap on distal side; 5–6, vertical sections, A.U.G.D. nos. F15284 and F15285, respectively, showing very thick, well-layered dorsal and ventral walls; enclosed annular and radial canals and chamber lumina connected to surface by tubular pores.

7–11 *Sherbornina cuneimarginata* Wade, n. sp.
> 7, megalospheric horizontal section, A.U.G.D. no. F15118e, showing two early and three late nepionic chambers, and three neanic chambers; 8–11, vertical sections, A.U.G.D. nos. F15117a and F15116, G.S.M.V. no. 54429, and A.U.G.D. no. F15117b, respectively, showing variation in outline, mainly due to length of ventral prolongations, prolongations in open communication with lumina, incomplete layering of dorsal wall, with traces of canal system visible, and pores penetrating wall; where plane of section is at an angle to prolongations, more than one ventral prolongation is cut below one annular chamber.

PLATE 3
All figures unretouched, × ca. 100.

1–3 *Sherbornina atkinsoni* Chapman
> 1, microspheric specimen, G.S.M.V. no. 54424, showing fourteen nepionic and five neanic chambers; traces of annular and radial canals visible in walls at right side; 2, megalospheric specimen, G.S.M.V. no. 54421, showing two early and five late nepionic chambers, and five neanic chambers; 3, megalospheric specimen, G.S.M.V. no. 54423, showing three early and four late nepionic chambers, and four neanic chambers.

4–6 *Sherbornina crassata* Wade, n. sp.
> 4, microspheric specimen, A.U.G.D. no. F15290, showing eleven nepionic and two neanic chambers; part of juvenile canal system of spiral and septal canals visible at distal sides of last two nepionic chambers; adult canal system of annular septal canals and radial canals, present in succeeding chambers, visible above and on left side of specimen; 5, megalospheric specimen, A.U.G.D. no. F15287, showing three early and three late nepionic chambers, and three neanic chambers; strongly recrystallized; 6, megalospheric specimen, A.U.G.D. no. F15289, showing two early and two late nepionic chambers, and two neanic chambers.

7–10 *Sherbornina cuneimarginata* Wade, n. sp.
> 7, microspheric or perhaps intermediate specimen, A.U.G.D. no. F15115, showing nine nepionic and two neanic chambers; 8, horizontal section, A.U.G.D. no. F15119, just below annular part of chambers, showing ventral prolongations alternating in position from chamber to chamber, each with a discrete wall, those of neighbouring prolongations touching; annular walls of last chamber visible; 9, megalospheric specimen, A.U.G.D. no. F15118c, with three early and two late nepionic chambers, and two neanic chambers; 10, megalospheric specimen, A.U.G.D. no. F15118g, with three early and two late nepionic chambers, and two neanic chambers.
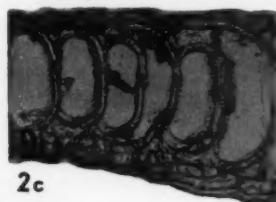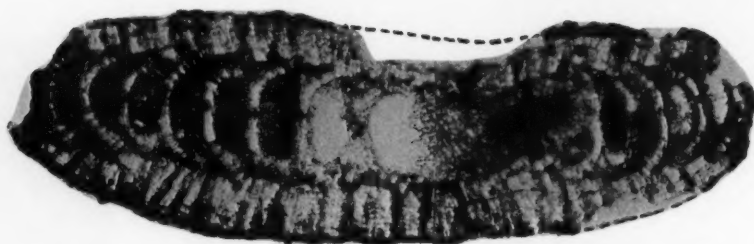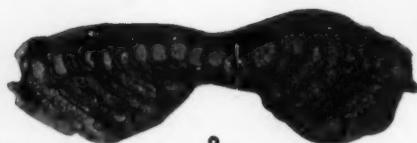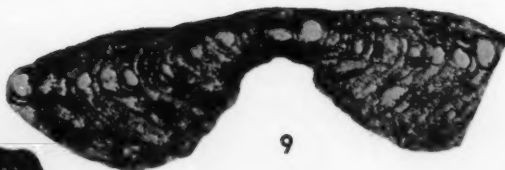
PLATE 1
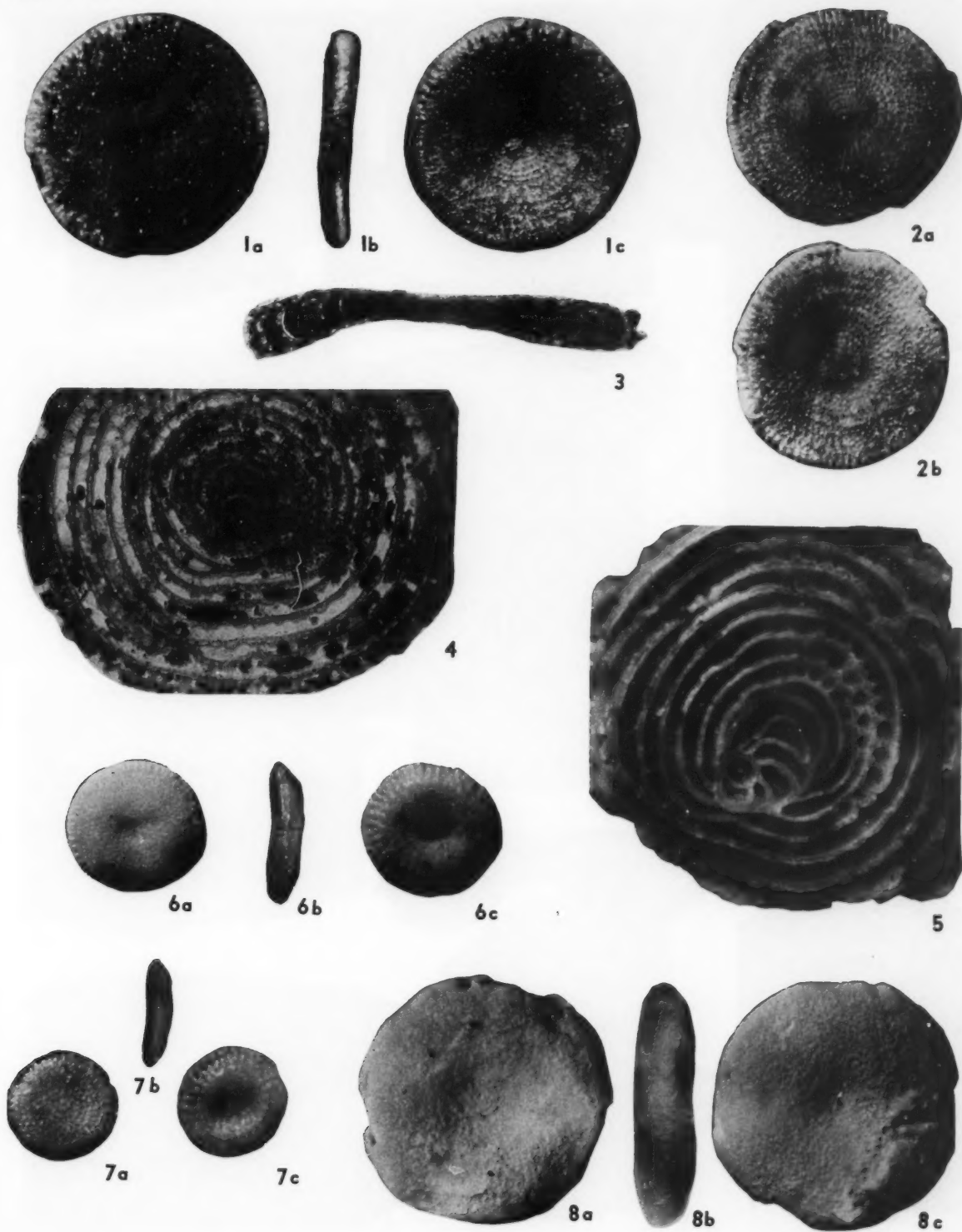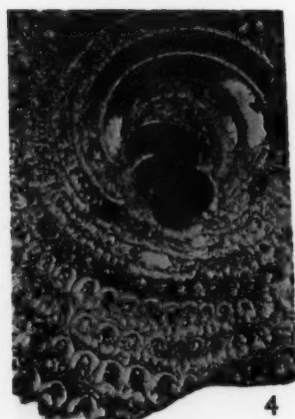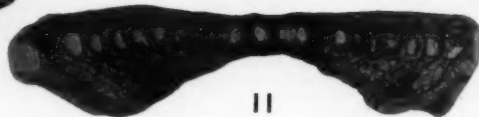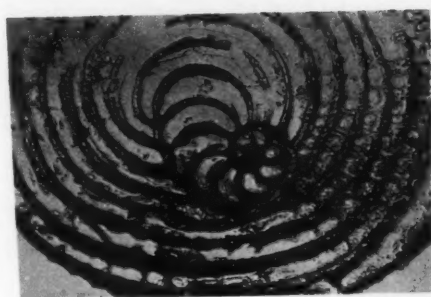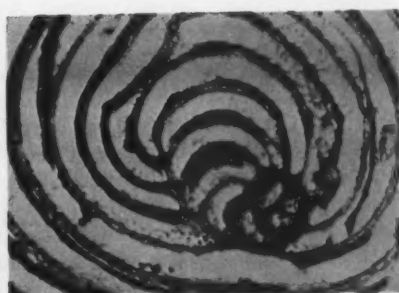
association with a younger fauna. *Sherbornina crassata* is not known from Victoria.

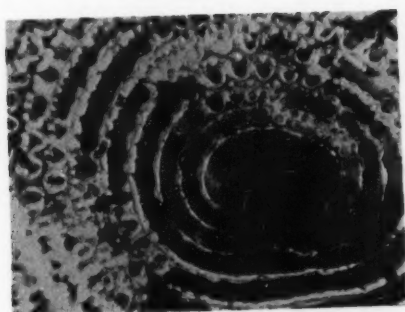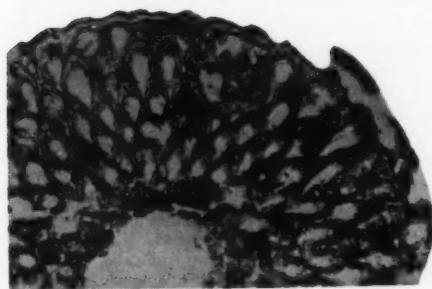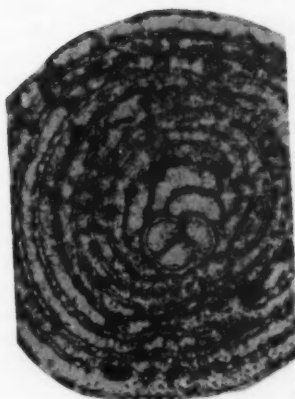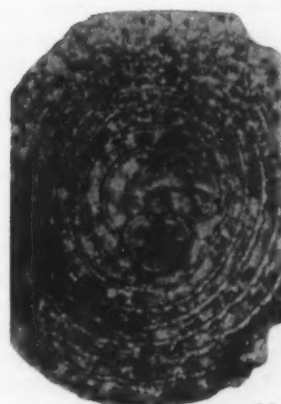In the Adelaide Basin, *Sherbornina atkinsoni* occurs on the east coast of Yorke Peninsula in beds of Oligocene age, the equivalents of the Port Willunga beds. This species occurs throughout the Port Willunga beds in the coastal section north and south of Port Willunga (Reynolds, 1953). In Victoria, the evidence at present available suggests that the oldest occurrence of *Sherbornina atkinsoni* is that on the west side of Bells Headland in the Torquay district (B. 101 of Raggatt and Crespin, 1955, p. 127). The present writers consider this to be post-Eocene in age (Table 1). In the Torquay district, the range of *Sherbornina atkinsoni* corresponds exactly with that of *Victoriella plecte* Chapman (Raggatt and Crespin, 1955, tables 5 and 7), and is separated from the earliest occurrence of *Globoquadrina dehiscens* (Chapman, Parr and Collins) by a considerable stratigraphic interval, and by an even greater interval from the earliest occurrence of *Sherbornina cuneimarginata*. In the Aire district, the range of *Victoriella plecte* extends below that of *Sherbornina atkinsoni*, but after the disappearance of *Victoriella plecte*, *Sherbornina atkinsoni* extends upward into the range of *Globoquadrina dehiscens* but does not overlap that of *Sherbornina cuneimarginata*. The only evidence from Victoria that the ranges of *Sherbornina atkinsoni* and *Sherbornina cuneimarginata* overlap is seen at Maude, where both species occur in the base of the "upper Maude limestone." In South Australia, members of the Port Willunga beds occur inland from Port Willunga that are higher than those exposed in the coastal sections. *Sherbornina cuneimarginata* makes its appearance within the range of *Sherbornina atkinsoni* and extends above it. The occurrence of these two species in association should prove to be a useful marker event for stratigraphic correlation.

Sherbornina cuneimarginata ranges almost up to the lowest occurrence of *Lepidocyclina gippslandica* in the River Murray cliffs at Blanchetown, South Australia. In Victoria, similarly, it has not been found in association with *Lepidocyclina* but occurs in similar facies a short stratigraphic distance below the earliest occurrence of *Lepidocyclina*, both at Batesford and in the Longford district of Gippsland. In these districts the earliest *Lepidocyclina* is *Lepidocyclina gippslandica* Crespin (1943). In the Aire and Maude districts, extrapolation of occurrences of *Sherbornina cuneimarginata* places them not far below occurrences of *Lepidocyclina*. The upper limit of this species, and of the genus so far as it is now known, is thus dated as Lower Miocene, just before the invasion of this region by *Lepidocyclina*.

TABLE 1

DISTRIBUTION OF SPECIES OF SHERBORNINA

	South Australia		Western Victoria	Eastern Victoria	Tasmania
	Adelaide Basin	Murray Basin			
Lower Miocene	cu	cu	cu (B, T, A)	cu (L)	
?	a, cu	a, cu (M)			
Oligocene	a	a	a(A,T,W)		a
Upper Eocene	cr	cr			

Abbreviations: cr = *Sherbornina crassata;* a = *Sherbornina atkinsoni;* cu = *Sherbornina cuneimarginata*. Localities in Victoria: A = Aire district; T = Torquay district; W = Waurn Ponds; M = Maude; B = Batesford; L = Longford district.

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ABSTRACT: *Three new species of holothurian sclerites,* Thuroholia marginata, Achistrum frizzelli, *and* Rota martini, *from the Lower Mississippian Escabrosa limestone of Cochise County, Arizona, are described and figured. The new genus* Rota *is described.*

Holothurian sclerites from the Mississippian Escabrosa limestone, Arizona

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INTRODUCTION

The holothurian sclerites described in this paper were encountered by the senior author while identifying Paleozoic fossils collected by the junior author. It was decided to record their occurrence and to describe them because the distribution and character of fossil holothurians are very poorly known, although the fossils are of considerable paleontologic interest and are of potential value in stratigraphic work. The senior author is responsible for the paleontologic descriptions and interpretations; all geologic and stratigraphic data have been provided by the junior author.

The Pedregosa Mountains are situated near the southeastern corner of Cochise County, Arizona (text-fig. 1 a). Exposures of the Escabrosa limestone are found along the northern, eastern and southwestern portions of the range (text-fig. 1 b). The eastern outcrops, near Boss Ranch, afford a well-exposed, complete section, but the others are complicated by faulting and are incomplete.

The Escabrosa limestone is conformably overlain by the Upper Mississippian Paradise formation and, in turn, rests conformably on Upper Devonian strata. It is of Lower Mississippian age. The lithology and fauna of the Escabrosa limestone in the Pedregosa Mountains are similar to those of the type section in the Mule Mountains near Bisbee, Arizona (Ransome, 1904, pp. 42–44), with the exception that here the formation attains a maximum thickness of 1275 feet, whereas in the type locality it does not exceed 800 feet.

The Escabrosa limestone is characterized by blue-gray weathering, thick-bedded, coarse-grained cherty crinoidal calcarenite. The clastic nature of the limestone is especially apparent on weathered surfaces. Broken and slightly abraded fragments of crinoids are cemented together by calcite which has generally filled the intergranular pore space, resulting in quite resistant strata. Locally, however, clastic grains are in close contact and little cement has been added; such beds have a crumbly aspect and are more or less friable. Beds of dense, fine-grained or aphanitic limestone are present, but they are generally thin and subordinate to the crinoidal calcarenite. Nodules, stringers and oval-shaped pillows of chert are abundant in much of the limestone, and are so abundant in some strata that they impart a thin-bedded aspect.

A light-gray weathering, thick-bedded, medium-grained dolomite member in the lower part of the Escabrosa limestone is the only variant from the typical lithology described above. It is a distinct stratigraphic unit in the Pedregosa Mountains, and ranges from 120 to 190 feet thick (text-fig. 1 c).

The rock sample containing the holothurian sclerites was approximately $2 \times 2 \times 3$ inches in size and consisted of fine to medium-grained gray crinoidal limestone. Digestion in dilute acetic acid (approximately one part of glacial acetic acid in ten parts of water) left a residue composed primarily of silicified crinoid columnals. Holothurian sclerites were the next most prominent fossils, and there were also a
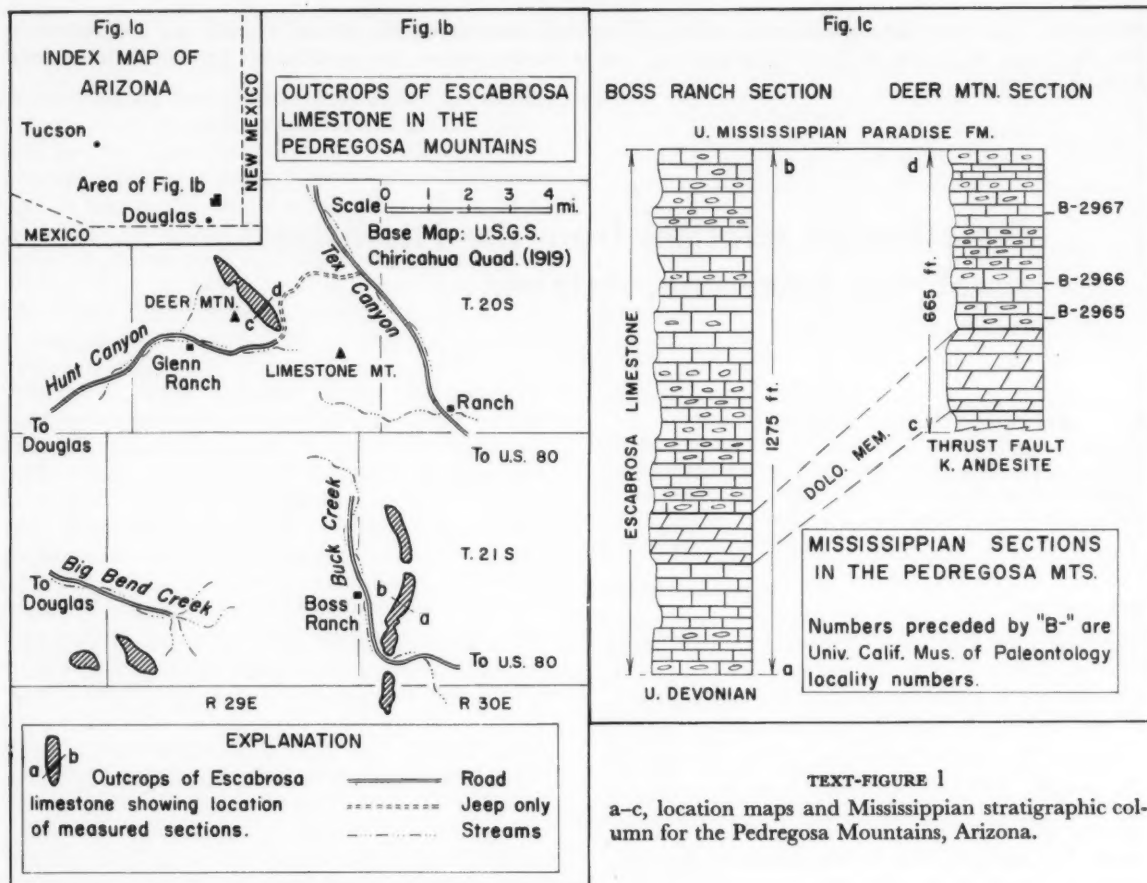
a–c, location maps and Mississippian stratigraphic column for the Pedregosa Mountains, Arizona.

few sponge spicules, brachiopod fragments, and rare bits of indeterminate black organic matter. Inorganic material consisted of a very small quantity of subrounded quartz silt. The following megafossils were obtained from the same measured section (text-fig. 1 c):

Locality B-2965 — *Euomphalus* sp.

Locality B-2966 — *Triplophyllites* sp.
  Composita humilis (Girty)?
  Rhipidomella burlingtonensis
   (Hall)
  Spirifer cf. *S. centronatus* Winchell

Locality B-2967 — Unidentified tetracorals
  Athyris? sp.
  Camarotoechia metallica
   (White)?
  Chonetes? sp.
  Composita humilis (Girty)?

  Crurithyris sp.
  Linoproductus gallatinensis
   (Girty)
  Rhipidomella thiemei (White)
  Spirifer sp.
  Myalina? sp.
  Holothurian sclerites

The sclerites have been replaced by solid granular quartz, apparently without alteration of their gross outlines. Growth of individual quartz crystals did not, however, always cease at the boundary of the sclerite, and, as a result, most of the surface of each fossil is composed of irregular knobs. These knobs obscure any fine sculpture which may have existed in the original, and the possible presence of dentition on the rim or within the perforations of plate or wheel-like sclerites cannot be proven or disproven. It is assumed, however, that no dentition existed, because portions of the outlines of some perforations and of some rims are smooth. Material of an obviously

foreign nature adhering to the sclerites has been ignored in the preparation of illustrations, but any doubtful irregularities are shown. The figures were prepared by bleaching inked photomicrographs.

The classification and morphologic terminology of Frizzell and Exline (1955) are followed wherever applicable.

This paper is a contribution from the Museum of Paleontology and the Department of Geology of the University of California at Berkeley. Type specimens are deposited in the collections of the museum, and numbers preceded by "UCMP" refer to the type collections of the Museum of Paleontology, University of California, Berkeley 4, California. J. Wyatt Durham criticized the manuscript, and C. M. Gilbert gave aid and encouragement during the field phase of the project. The authors, however, assume full responsibility for the content of the paper.

SYSTEMATIC DESCRIPTIONS

Phylum ECHINODERMATA

Class HOLOTHUROIDEA

Family CALCLAMNIDAE Frizzell and Exline, 1955

Genus **Thuroholia** Gutschick, 1954

Frizzell and Exline (1955) have included *Eocaudina septaforaminalis* Martin as the type species within a genus of holothurian sclerites ("*Eocaudina* Martin, emend. Frizzell and Exline") composed of perforated plates, and have explained their action as follows: "Martin's reconstruction of the species, as a wheel, is erroneous. Our illustrations, traced from the type figure and copied from a photomicrograph of a topotype..., show the sclerite to be an unquestionable sieve-plate" (Frizzell and Exline, 1955, p. 90). We accept without reservation Frizzell and Exline's morphologic concept of a genus of perforated plates, but we question the position of *Eocaudina septaforaminalis* Martin within the genus. The senior author saw Martin's specimens of *Eocaudina septaforaminalis* before and after their transfer to permanent slides, and is able to vouch for Martin's reconstruction of the species as a subhexagonal plate "with a single central perforation, an intermediate ring of six perforations and an outer ring of approximately eleven perforations" (Martin, 1952, pp. 728–729). Unfortunately, Martin's material consisted entirely of very fragile silicified specimens, and none of the five or six specimens of *Eocaudina septaforaminalis* survived transfer in an undamaged condition from the wet-sieved residue to a permanent slide. The reconstructed holotype is merely the most complete specimen left after manipulation. Thus, if Martin's observations are accepted, *Eocaudina septaforaminalis* is a wheel and a member of the

Theelidae, and the name *Eocaudina* is unavailable for a genus of perforated plates. The name *Thuroholia* Gutschick, 1954, must then be applied to the genus, with *Thuroholia croneisi* Gutschick as the type species.

Thuroholia marginata Langenheim and Epis, new species
Plate 1, figures 7–16

Description: Sclerite a flat to slightly arched perforated plate, small to very large for the genus; outline subcircular to rounded subtriangular; periphery generally smooth with a few incompletely bounded perforations and often with single peripheral notch; peripheral notch rounded at margin, angulate at bottom; many perforations roughly arranged in rows intersecting at 60° and 120°; perforations of central area 0.03 mm. to 0.15 mm. in diameter, surrounded by a border of markedly small perforations; perforations generally circular to subcircular, separated by bars varying from one-third as wide to as wide as the adjacent perforation. Dimensions of figured specimens are shown in Table 1.

The specific name is derived from the Latin *marginatus*, border.

Types: Holotype, UCMP no. 37559; paratypes, UCMP nos. 37560–37568, inclusive.

Discussion: Thuroholia marginata is easily distinguishable from all other species of perforated plates excepting *Thuroholia mortenseni* (Frizzell and Exline), *Thuroholia scotica* (Frizzell and Exline), and *Thuroholia guembeli* (Frizzell and Exline), because of its pattern of larger perforations surrounded by a border of smaller holes. *Thuroholia marginata* most closely resembles *Thuroholia mortenseni* but is a much larger sclerite; the smallest known specimen of *Thuroholia marginata* is larger than the reported size of *Thuroholia mortenseni*. In addition, small specimens of *Thuroholia marginata* have less than twenty perforations, in contrast to ninety in the holotype of *Thuroholia mortenseni. Thuroholia scotica* and *Thuroholia guembeli* also have a pattern of larger perforations in the central portion of the sclerite, but *Thuroholia scotica* has an abundantly notched margin, and *Thuroholia guembeli* has irregular perforations and a spinose margin.

Eighty-six specimens of *Thuroholia marginata* were available for study.

Family ACHISTRIDAE Frizzell and Exline, 1955

Genus ACHISTRUM Etheridge, 1881, emend. Frizzell and Exline, 1955

Achistrum frizzelli Langenheim and Epis, **new species**
Plate 1, figures 1–6

Description: Sclerite hook-shaped; shank straight, expanding slightly toward spear; spear short, straight to

TABLE 1

DIMENSIONS (IN MM.) OF *Thuroholia marginata*

	Holotype 37559 Fig. 7	Paratype 37560 Fig. 8	Paratype 37561 Fig. 9	Paratype 37562 Fig. 10	Paratype 37563 Fig. 11	Paratype 37564 Fig. 12	Paratype 37565 Fig. 13	Paratype 37566 Fig. 14	Paratype 37567 Fig. 15	Paratype 37568 Fig. 16
Max. diam.	0.7	0.87	0.63	0.67	0.48	0.49+	0.68+	0.29	0.42	0.30
Approx. diam. central perf.	0.05	0.1	0.04	0.09	0.05	0.05	0.14	0.03	0.07	0.02
Approx. diam. border perf.	0.02	0.03	0.02	0.03	0.08	0.01	0.04	0.01	0.02	0.01
Approx. space central perf.	0.04	0.07	0.03	0.06	0.04	0.03	0.06	0.03	0.06	0.01
No. perfs.	53	53	60	30	23+	24+	15+	16+	11	23

TABLE 2

DIMENSIONS (IN MM.) OF *Achistrum frizzelli*

	Holotype 37553 Fig. 1	Paratype 37554 Fig. 2	Paratype 37555 Fig. 3	Paratype 37556 Fig. 4	Paratype 37557 Fig. 5	Paratype 37558 Fig. 6
Length	0.82	0.62+	0.54+	0.65+	0.55+	0.47+
Width	0.24	—	0.22	0.24	0.28	0.26
Max. diam. shank	0.09	0.08	0.09	0.11	0.10	0.10
Thickness of eye	0.05	0.06	—	—	—	—
Outer diam. eye	0.10	0.11	—	—	—	—
Long diam. inside eye	0.04	0.05	—	—	—	—
Short diam. inside eye	0.015	0.02	—	—	—	—

TABLE 3

DIMENSIONS (IN MM.) OF *Rota martini*

|	Paratype 37569 Fig. 17	Paratype 37570 Fig. 18	Paratype 37571 Fig. 19	Paratype 37572 Fig. 20	Paratype 37573 Fig. 21	Paratype 37574 Fig. 22	Paratype 37575 Fig. 23	Holotype 37576 Fig. 24	Paratype 37577 Fig. 25
No. spokes	6	4	4	5	6	4	5	5	8
Diameter	0.24	0.3	0.42	0.20	0.52	0.39	0.25	0.41	0.29
Interspace diameter	0.04	0.05	0.06	0.03	0.08	0.07	0.04	0.06	0.04
Width spokes	0.03	0.04	0.05	0.03	0.04	0.05	0.02	0.02	0.03
Width rim	0.03	0.03	0.07	0.03	0.09	0.04	0.03	0.04	0.03
No. rim perfs.	0	0	15	0	11+	4	0	7	0
Diam. rim perfs.	—	—	0.02-0.05	—	0.02-0.04	0.02	—	0.03	—
Diam. central perforation	0.01	—	0.01	—	0.02	0.01	0.01	0.01	—
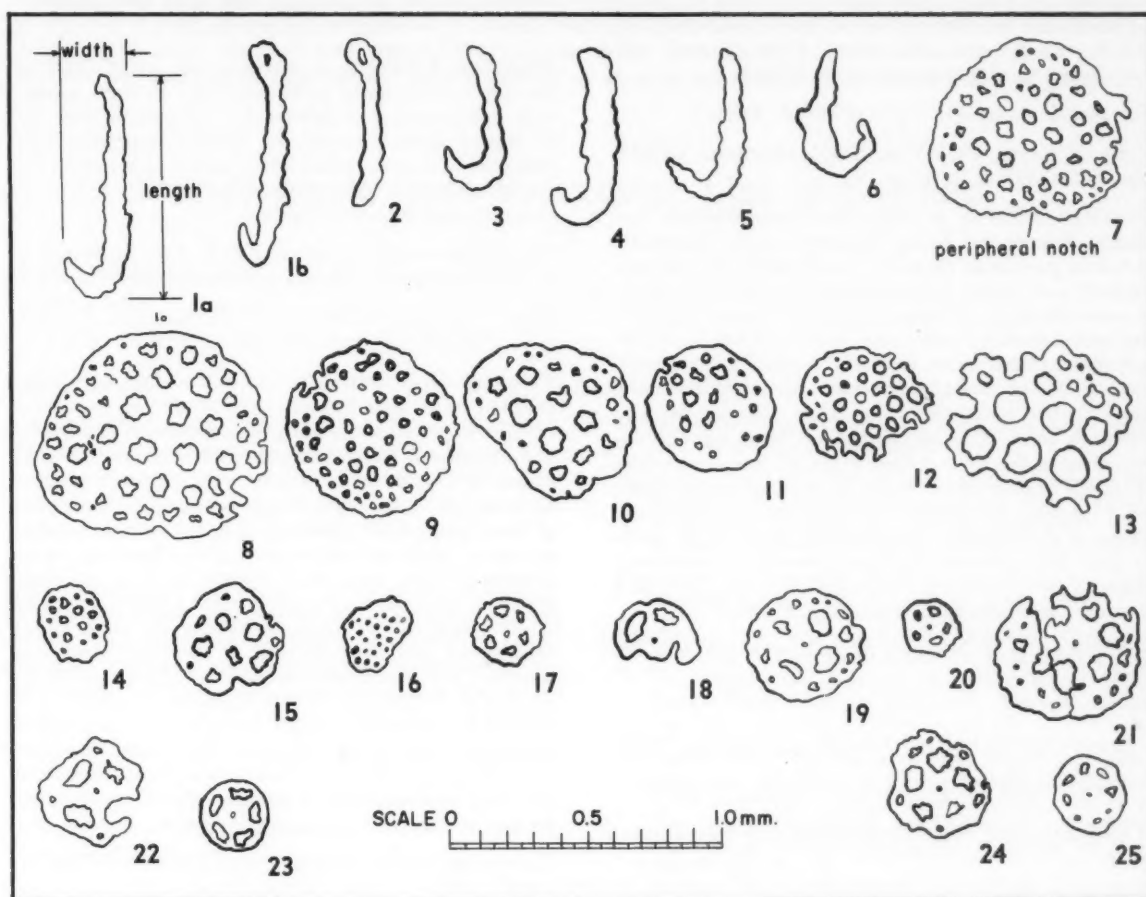
PLATE 1
All figures × 43.

1–6 *Achistrum frizzelli* Langenheim and Epis, n. sp.
1, holotype, UCMP no. 37553: a, lateral view; b, front view; 2, paratype, UCMP no. 37554, front view of fragmentary specimen showing larger eye-opening; 3–6, paratypes, UCMP nos. 37555–37558, lateral views of fragmentary specimens, showing variation in hook form.

7–16 *Thuroholia marginata* Langenheim and Epis, n. sp.
7, holotype, UCMP no. 37559; 8–16, paratypes: 8, UCMP no. 37560, very large specimen with well developed peripheral notch; 9, UCMP no. 37561, medium-sized specimen lacking peripheral notch; 10, UCMP no. 37562, medium-sized subtriangular specimen with large perforations; 11, UCMP no. 37563, small subcircular specimen; 12, UCMP no. 37564, small oval specimen with very regularly spaced perforations; 13, UCMP no. 37565, fragment with exceedingly large perforations; 14, UCMP no. 37566, very small oval specimen; 15, UCMP no. 37567, small specimen with widely spaced perforations and well developed peripheral notch; 16, UCMP no. 37568, very small subtriangular specimen.

17–25 *Rota martini* Langenheim and Epis, n. gen., n. sp.
17–23, paratypes: 17, UCMP no. 37569, six-spoked wheel with imperforate rim; 18, UCMP no. 37570, fragmentary four-spoked wheel with imperforate rim; 19, UCMP no. 37571, four-spoked wheel with many rim perforations; 20, UCMP no. 37572, five-spoked wheel with imperforate, distinctly pentagonal rim; 21, UCMP no. 37573, six-spoked wheel with many rim perforations; specimen photographed as shattered on slide; 22, UCMP no. 37574, four-spoked wheel with rim perforations at junctions of spokes and rim; 23, UCMP no. 37575, five-spoked wheel with imperforate rim; 24, holotype, UCMP no. 37576, five-spoked wheel with intermediate number of rim perforations; 25, paratype, UCMP no. 37577, eight-spoked wheel with imperforate rim.

recurved; eye oval, slightly excentric to axis of shank, perpendicular to plane of spear and moderately inclined toward spear. Dimensions of the holotype and five figured paratypes are shown in Table 2.

The specific name is in honor of Don L. Frizzell.

Types: Holotype, UCMP no. 37553; paratypes, UCMP nos. 37554–37558, inclusive.

Discussion: Achistrum frizzelli differs from *Achistrum barthonium* Frizzell and Exline, *Achistrum ludwigi* (Croneis), *Achistrum permianum* (Spandel), and *Achistrum triassicum* Frizzell and Exline in possessing a straight shank; it is separable from *Achistrum bartensteini* Frizzell and Exline and *Achistrum barthonium* Frizzell and Exline by the fact that its shaft tapers toward the eye. The extremely short spears of *Achistrum permianum* and *Achistrum triassicum* further distinguish them from *Achistrum frizzelli.* *Achistrum issleri* (Croneis) differs in the shape and inclination of the eye. *Achistrum frizzelli* most resembles *Achistrum brownwoodensis* (Croneis) and *Achistrum nicholsoni* Etheridge, but differs from the former in its narrowly elliptical eye-opening and from the latter in its much greater size. *Achistrum bohemicum* Prantl is a perforated plate (Prantl, 1947, p. 30, text-figs. 1–4), and is a species of *Eocaudina* rather than of *Achistrum.*

Six specimens of *Achistrum frizzelli* were available for study.

Family THEELIDAE Frizzell and Exline, 1955

Genus **Rota** Langenheim and Epis, **new genus**

Type species: Rota martini Langenheim and Epis, n. gen., n. sp.

Description: Sclerite wheel-shaped; four to eight short spokes in known specimens, flat to gently arched; rim appears to be in plane of spokes, imperforate or perforated by few to many small holes; central hub with a single, centered small perforation or pit.

The generic name is derived from the Latin *rota*, n.f., a wheel.

Discussion: Rota most closely resembles *Acanthotheelia, Paleochiridota,* and *Theelia.* It is distinguished from *Acanthotheelia,* however, by its lack of marginal spines. The central pit or perforation of *Rota* is quite small (approximately 0.1 mm. in diameter) and may be obscured by silicification, but its presence is sufficient to distinguish the genus from *Theelia* and *Paleochiridota.* *Paleochiridota* also possesses a raised central hub, which is lacking in *Rota.*

Rota martini Langenheim and Epis, **new species**
Plate 1, figures 17–25

Description: Sclerite a concavo-convex wheel; outline circular to irregularly polygonal; four to eight spokes with subtriangular to subcircular interspaces; rim lies in curved surface containing spokes, imperforate to perforate with many small perforations; hub large with single small perforation or pit. Measurements of figured specimens are shown in Table 3.

The specific name is in honor of W. R. Martin, describer of the oldest known unequivocal holothurian sclerite.

Types: Holotype, UCMP no. 37576; paratypes, UCMP nos. 37569–37575, inclusive, and UCMP no. 37577.

Discussion: All of the sclerites referred to *Rota* have been assigned to a single broadly defined species, variations being interpreted as resulting from fortuitous differences in the number of spokes and from different developmental stages. The number of spokes, ranging from four to eight, is believed to represent variation in the basic plan of the sclerite. Each sclerite presumably starts as a disc and then develops four to eight rays. Each star then acquires a rim and, with further growth, develops perforations in the rim opposite each spoke. Continued development of the sclerite results in perforations throughout the circumference of the rim. Strict application of the artificial morphologic system of classification now applied to fossil holothurian sclerites would require recognition of eight or nine species of *Rota* among the specimens available. The overall morphologic similarity of the sclerites, however, and their occurrence in a single small sample suggest that it might be best to recognize only a single species.

Thirty-one specimens of *Rota martini* were available for study.

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ABSTRACT: *In the present paper, the author deals with two main groups of forms of* Frondicularia *from the Lower Lias of England. A group of smooth forms assigned to* Frondicularia brizaeformis Bornemann *is described and the variations in the growth stages discussed. Ornamented forms belonging to the* Frondicularia sulcata Bornemann *plexus are also described, and the significance and range of the chief variants are discussed and illustrated with an evolutionary diagram.*

Frondicularia from the Lower Lias of England

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INTRODUCTION

In 1950 (Barnard, 1950a, p. 371), I drew attention to the value of the various species of *Frondicularia* in the stratigraphy of the Lower Lias. Since this work was published, more detailed evidence has become available, not only from study of faunas from a large number of localities, but also from study of those obtained from cores penetrating the Lias. This almost complete cored sequence through the Lias was obtained from H. M. Geological Survey's borehole at Stowell Park, Northleach, Gloucestershire. A number of Terquem's specimens have also been studied. The results I obtained (1950a) have proved to be substantially correct, but a more complete history of the species of *Frondicularia* from the Lias may prove of value, and with this in mind the present paper was written. A survey of the whole family Lagenidae is at present being carried out.

SYSTEMATIC DESCRIPTIONS

Family LAGENIDAE

Genus **Frondicularia** Defrance, 1826

Genotype: Renulina complanata Defrance, 1824.

Both Cushman (1940, p. 201) and Glaessner (1945, p. 131) state that in the microspheric generation the early chambers may be in a curved series. This character has not been found in the species from the Lias with the exception of *Frondicularia paradoxa* Berthelin, a form which may have a different ancestry.

A. Smooth forms

Frondicularia brizaeformis Bornemann
Text-figures 1A–F, 2A–F

Frondicularia brizaeformis BORNEMANN, 1854, Liasform. Göttingen, p. 36, pl. 3, figs. 17a–d, 18a–c, 20a–b. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 67, pl. 6, fig. 24. – BARNARD, 1950, Geol. Soc. London, Quart. Jour., vol. 105, p. 369, text-fig. 7h. – USBECK, 1952, Neues Jahrb. Geol. Pal., Abh., vol. 95, p. 393, pl. 17, fig. 45.

Frondicularia impressa TERQUEM, 1864, Acad. Imp. Metz, Mém. vol. 44, p. 379, pl. 7, fig. 21a–d.

Frondicularia intumescens BORNEMANN, 1854, Liasform. Göttingen, p. 36, pl. 3, fig. 19a–c. – BLAKE, 1876, Yorkshire Lias, p. 468, pl. 19, fig. 21. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 67, pl. 6, fig. 27.

Frondicularia cf. *intumescens* Bornemann. – BURBACH, 1886, Zeitschr. Naturw., vol. 59, p. 49, pl. 2, figs. 38–41.

Frondicularia major BORNEMANN, 1854, Liasform. Göttingen, p. 36, pl. 3, fig. 21a–c. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 68, pl. 7, fig. 2a–b. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 155, pl. 5, fig. 68.

Frondicularia nitida TERQUEM, 1858, Acad. Imp. Metz, Mém., vol. 39, p. 592, pl. 1, fig. 9a–c. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 68, pl. 7, figs. 1, 3. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 155, pl. 2B, fig. 19; pl. 4, fig. 55; pl. 5, fig. 35.

Frondicularia spatulata Terquem. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 66, pl. 6, fig. 23.

Frondicularia sacculus TERQUEM, 1866, Sixième mém. foram. Lias, p. 482, pl. 19, fig. 20a–b. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 68, pl. 7, fig. 4.

Description: The test is generally large and robust, but some variation exists, occasionally resulting in small specimens. The cross-section is swollen, biconvex. The chambers are chevron-shaped or arched toward the aperture, and number three to twelve, but generally six. After a globular proloculus, the first three or four chambers increase rapidly in size, so that the test has strongly divergent margins; thereafter the breadth of the chambers remains the same, so that the test becomes parallel-sided. The surface is smooth except where the sutures become slightly constricted; usually, however, the latter are flush with the surface and scarcely visible. Occasionally, changes in the growth rate produce either smaller or larger end chambers, and greatly alter the overall shape of the test. The aperture is central and terminal, elongate radiate or crenulate.
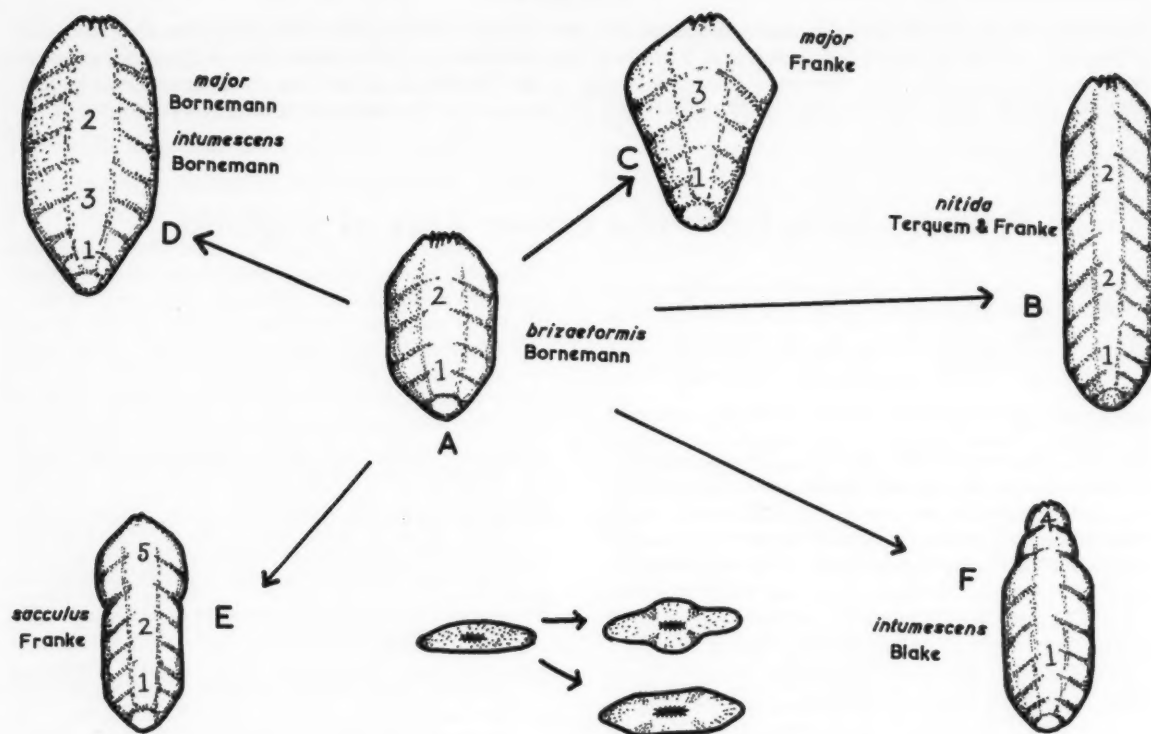
TEXT-FIGURE 1

A–F, specimens of *Frondicularia brizaeformis* Bornemann, showing variation and growth stages (numbered). Varietal or specific names given to these forms by selected authors are also shown.

Material: Several hundred specimens from a number of localities.

Depository: British Museum (Natural History); Geological Survey and Museum; and Barnard Collection, London.

Horizons: Lower Lias, *angulatum* to *semicostatum* zones.

The brizaeformis gens

Since 1854, when Bornemann first described a group of smooth species of *Frondicularia* from the Lias, various authors, including Terquem, Blake and Franke, have erected new species, most of which appear to be either genomorphs or growth stages of one species, as I noted in 1950 (Barnard, 1950*a*). Further evidence has now been obtained, and a more complete description of the species group can be attempted. The growth stages of the various forms are described, followed by a discussion of the species erected or described by other authors. In text-figure 1 the main variants have been figured, and the growth stages have been numbered as follows:

Stage 1: The proloculus is followed by three or four chambers increasing rapidly in size, so that the test is triangular.

Stage 2: The next chambers are chevron-shaped and of equal width, giving a parallel-sided form. This stage may be emphasised, producing an elongate test.

Stage 3: Here the small initial stage (1) is emphasised, so that the test has strongly divergent sides for six or more chambers.

Stage 4: The end chambers often decrease to about half the width and are constricted, the test becoming fusiform, sometimes irregularly.

Stage 5: This is an alternative to Stage 4; the end chambers may increase in size, and when the increase is irregular, it may occur in single chambers or in groups of chambers, so that there appears to be a sudden marked change in the growth rate, giving an appearance of rejuvenation.

A combination of one or more of the growth stages listed above produces all the "species" that have been proposed. There is great variation in the size of the individuals at some horizons. The same trends in the stock are repeated at several widely separated intervals, for example, in the Oxford Clay and Kimmeridge Clay; this will be discussed later in a further paper.

The forms shown in text-figure 1, selected from various horizons, have been compared with the figures given by earlier authors or, when possible, with actual specimens. The list below shows comparisons that have been made, and the names of the variants proposed by some of the earlier authors have been added to text-figure 1.

Form A = *brizaeformis* Bornemann, 1854, pl. 3, figs. 17a–c, 18a–c, 20a–b.

Form B = *nitida* Terquem, 1858, pl. 1, fig. 9a, c; Franke, 1936, pl. 7, fig. 1; Bartenstein and Brand, 1937, pl. 4, fig. 55.

Form C = *major* Bornemann, 1854, pl. 3, fig. 21a–c; Franke, 1936, pl. 7, fig. 2b.

Form D = *major* Franke, 1936, pl. 7, fig. 2a; *nitida* Bartenstein and Brand, 1937, pl. 2B, fig. 19.

Form E = *sacculus* Terquem, 1866, pl. 19, fig. 20a–b; Franke, 1936, pl. 7, fig. 4.

Form F = *nitida* Terquem, 1858, pl. 1, fig. 9b; Franke, 1936, pl. 7, fig. 3; *intumescens* Blake, 1876, pl. 19, fig. 21; cf. *intumescens* Burbach, 1886, pl. 2, figs. 38–41.

Four of Terquem's slides labelled *Frondicularia nitida* Terquem, deposited in the Natural History Museum, Paris, were examined and identified as indicated below. Some forms are figured in text-figure 2.

Slide A: Two specimens; one is *Frondicularia terquemi* d'Orbigny, the other is a parallel-sided elongate form of *Frondicularia brizaeformis* (Spec. A_1) and is figured here (text–fig. 2A).

Slide B: Three specimens, all *Frondicularia brizaeformis*.

Slide C: Two specimens; one, a greatly elongated form (Spec. C_1), is figured here (text-fig. 2F).

Slide D: Seven specimens, all *Frondicularia brizaeformis* (Specs. D_1, D_2, D_3, D_6); they show slight variation in the shape of the end chambers (see text-fig. 2B–E).

All the forms mentioned above occur in the Lower Lias, and no stratigraphic significance can be attached to any form within the group. It is proposed that all forms be referred to the one species *Frondicularia brizaeformis* Bornemann. This name is to be applied, however, only to forms confined to the Lower Lias; convergent homoemorphs found in later strata will be discussed elsewhere.

Frondicularia paradoxa Berthelin
Text-figure 2G–J

Frondicularia paradoxa BERTHELIN, 1879, Rev. Mag. Zool., ser. 3, vol. 7, p. 33, pl. 1, figs. 12–17. – ISSLER, 1908, Palaeontographica, vol. 55, p. 58, pl. 3, figs. 119–121.

Flabellina paradoxa (Berthelin). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 91, pl. 9, figs. 10–11. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, pl. 4, fig. 63a–e.

Plectofrondicularia paradoxa (Berthelin). – MACFADYEN, 1941, Roy. Soc. London, Philos. Trans., ser. B, vol. 231, no. 576, p. 66, pl. 4, figs. 67–68.

Description: The test varies from elliptical to rhomboidal, and is composed of four to ten chambers. Considerable variation occurs in the initial stages. The globular proloculus, which may or may not be provided with a small spine, is followed by a second chamber which shows little or no overlap onto the proloculus, the aperture being distinctly off-centre. The third chamber is variable; it may be inverted V-shaped, with one arm of the chevron overlapping onto the second chamber and the other being much longer and abutting directly onto the proloculus, or the third and subsequent chambers up to the fifth may be added alternately, with little or no overlap onto earlier chambers. The shell is completed by two to six almost symmetrical, equal chevron-shaped chambers. The surface of the test is smooth except for the sutures, which tend to be slightly raised above the surface. The aperture is central and terminal.

Depository: Geological Survey and Museum, London: no. Mik. (M) 458019.

Horizon: semicostatum zone.

Locality: Sample from 1630–1640 feet in Geological Survey boring at Stowell Park, Northleach, Gloucestershire, England.

Remarks: Macfadyen (1941, p. 65) assigned this species to the genus *Plectofrondicularia* Liebus, 1902, thereby placing it in the family Heterohelicidae. He states that *Plectofrondicularia* "is distinguished from *Frondicularia* by having the early chambers bolivine, only the later chambers becoming frondicularian. The aperture of the genotype was not described, the specimens being broken, but most adequately figured species later assigned to this genus have plain, not radiate, apertures." In view of the close resemblance of this species to many others with chevron-shaped chambers within the family
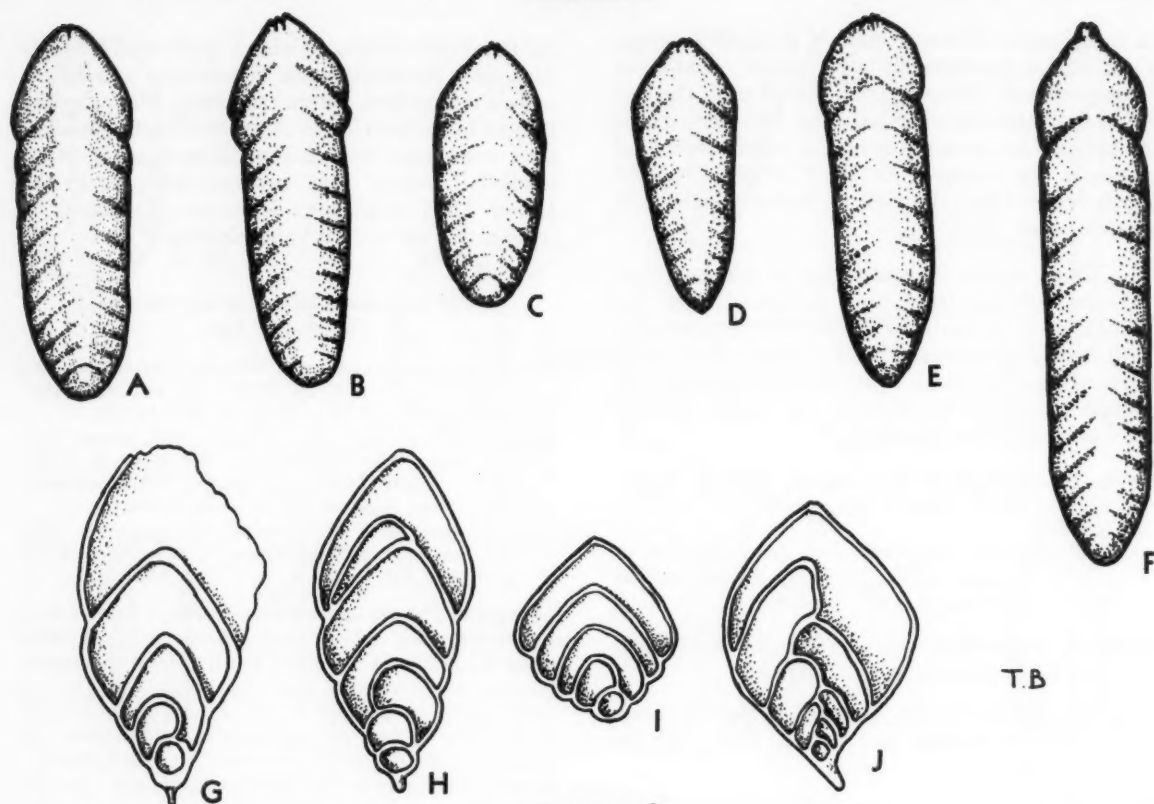
TEXT-FIGURE 2

A–F, *Frondicularia brizaeformis* Bornemann; all specimens are on slides A, C and D, labelled *Frondicularia nitida* Terquem, in the Natural History Museum, Paris: A, Spec. A_1; B, Spec. D_1; C, Spec. D_2; D, Spec. D_3; E, Spec. D_6; F, Spec. C_1. G–J, *Frondicularia paradoxa* Berthelin, four specimens selected to show variation in the initial stages of the test; all from the *semicostatum* zone at 1630–1640 feet in H. M. Geological Survey boring, Stowell Park, Northleach, Gloucestershire, England; slide no. Mik. (M) 458019.

Lagenidae, the variation occurring in the early chambers of frondiculariids from the Cretaceous, and the extreme variation of the apertures of the Lagenidae, it is for the present preferred to leave this species in the family Lagenidae.

B. Ornamented forms

I have already pointed out (Barnard, 1948, 1950a) the desirability of treating certain species groups each as an evolving plexus, and of describing the major trends in variation and evolution. It is considered that this approach will not only help to eliminate many specific names that have been proposed, but will also enhance our knowledge, for emphasis will be on similarities as well as differences. If, however, variations or evolutionary trends are of stratigraphic significance, then a case can be made out for the retention of certain specific or varietal names. Some ornamented forms of *Frondicularia* from the Lias appear to constitute such a plexus. The chief forms are figured on plates 1 and 2, and will be discussed below.

In the Rhaetic and pre-*planorbis* beds of the Lower Lias, many casts of *Frondicularia* occur, but unfortunately the ornament is not preserved. Near the base of the *planorbis* zone there is a rare small species of *Frondicularia* (Form A, pls. 1–2) with a flat, almost parallel-sided test ornamented with five weak longitudinal ribs which extend for almost the full length of the test, until they disappear on the end chamber. Over the early chambers the ribs are arranged progressively higher up the test on each side of the central rib. The aperture is central, terminal, radiate crenulate. Form A is unlike subsequent forms, but may be the ancestor of most later types.

Successive horizons in the *angulatum* zone show the gradual transition from a modified, larger form (Form A') closely resembling Form A to a large form with fourteen to sixteen ribs. This ornament of ribbing is the chief character showing evolution within the plexus. Form A' occurs in the basal horizons of the *angulatum* zone. The fine ribs have become coarser and more definite. Three of them extend down onto the apiculate proloculus. About the second or third chamber two more ribs commence. The straight sides of the test diverge at an angle of about 20° to 30°. Form A' is larger than Form A, but it is still rare and becomes extinct at about the middle of the *angulatum* zone. Form B represents the mode of the variation in the lower horizons of the *angulatum* zone. This is a more robust and stouter form, with eight ribs. It was derived through a number of intermediates from Form A'. There is a further increase in the number of ribs to ten or twelve.

In Form C the specimens become elongate, and the later chambers, particularly the end chamber, become slightly constricted at the sutures. In all these forms, A, A' and B, the apertural neck may be marked.

Form D has eight costae, as in Form B, but on the last and penultimate chambers the ribs curve slightly inward toward the aperture, following the general outline of the apertural face. Specimens from higher horizons in the *angulatum* and lower *bucklandi* zones show these trends carried still further, so that a large form (Form C') with up to fourteen straight ribs is frequent. Form D' has up to twelve ribs on the earlier and fourteen on the later chambers, but on the later chambers the ribs become curved and pinch in toward the aperture, following the general outline of the test. This pinching-in of the ribs may occur in two distinct stages, so that there appears to be a completely new set of independent ribs on the last few chambers. No constrictions occur at the sutures.

During *bucklandi* time these many-ribbed forms became degenerate and the costae fewer and coarser until, in the later part of this and the succeeding early *semicostatum* zone, a coarse-ribbed robust form developed, divisible into two important variants, Forms E and F. Form E has seven or nine ribs, and the short central costation developed on the proloculus extends over only a few chambers before disappearing suddenly. On either side of the central rib there are three or four other costae, arranged in steps along the early chambers, where they are often curved around the central costation, pinching

in where the latter dies out and then becoming straight over the remainder of the test except where they may become obsolete on the end chamber. Form F has no central rib, but the six coarse costae extend for almost the full length of the test, as in Form E.

During the later part of *semicostatum* time the outer pair of ribs in both Forms E and F degenerated, giving rise to the four-ribbed Form G. At first Form G is rare, but throughout the *turneri* zone the central mode of the population shifts from Forms E and F to Form G. In the *obtusum* zone, Forms E and F are rare and Form G predominates, making up a large part of the fauna. This change in the *obtusum* zone may be due to environment, for later, in the *raricostatum* zone, Forms E and F appear again in some abundance.

In the basal part of the *turneri* zone, where the four-ribbed Form G predominates, the two outer ribs shorten and disappear from the end chamber to produce Form H, which marks a passage to the bicostate Form I. However, at these horizons the stock appears to be so plastic that forms obviously derived from Forms E and F, usually the former, show four degenerate, nearly obsolete outer ribs, with two main central costations; these again approach Form H.

Coupled with the reduction from six or seven ribs to two, there is a change in the shape of the test, progressively, from the short and stout Forms E and F to the elongate, narrow Form I.

Throughout the *raricostatum* and *jamesoni* zones and in the lower part of the *ibex* zone, passage forms are found between the six- and four-ribbed and the two-ribbed tests. The centre of variation in successive populations oscillates until finally forms with four and two ribs, particularly the latter, dominate the scene. In the upper part of the *ibex* zone and in the *davoei* zone, the bicostate Form I gradually gains ascendancy, only to be replaced by the smooth Form J.

Within the lower part of the *davoei* zone, general degeneration of the ribs is found. There is a gradual passage from forms with two distinct ribs, through specimens in which the ribs are in the process of degeneration, and finally to smooth forms with no ribs but often with a slight central depression.

In the *jamesoni* zone there appears suddenly a form (Form K) with twelve to eighteen fine but well developed ribs. This form seems to arise independently of the main stock described above, and ranges from the middle *raricostatum* zone to the upper *davoei*

zone, with little change in ornament. At the top of the *lataecosta* subzone of the *davoei* zone, all the forms mentioned above appear to become extinct, possibly with the oncoming of the sandy and silty environment of the Middle Lias. The ranges of all of these forms are shown in Table 1.

TABLE 1

Middle Lias										
davoei					I–J					
ibex						K				
jamesoni										
raricostatum				G	H					
obtusum			E–F							
turneri										
semicostatum										
bucklandi			D							
angulatum		B, C								
planorbis	A–A′									
ZONES	RANGES OF THE FORMS									

Direction of evolution

Previous work

Few authors appear to have studied the foraminifera from a complete section of the Lias, and no doubt because of this the taxonomy of the species has become somewhat involved. However, Bartenstein and Brand (1937), in a paper based on suc-cessive horizons through the Lias, figured a series of specimens of *Frondicularia*, although the specific names they assigned tend to cloud the issue. A study of their figures shows that the general sequence in the evolution of this group is similar to that determined in Britain and described above.

Form A (see pls. 1–2) has escaped the notice of most previous authors, but Bartenstein and Brand (1937, pl. 1, fig. 12) figure a five-ribbed form from the *planorbis* zone which, although described as *Frondicularia sulcata* Bornemann, closely resembles the specimen here figured as Form A'. In pl. 2A, fig. 19a–b, and pl. 2B, fig. 20, these authors figure specimens from the Lias α (*angulatum* and *bucklandi* zones) having nine ribs, intermediate between our Forms B and C. Their pl. 2B, fig. 23, shows a specimen with four ribs, two of which are almost obsolete; it is referred to *Frondicularia bicostata* d'Orbigny. This identification must be open to doubt unless this is the earliest known record of this species, the penultimate form of the whole *Frondicularia sulcata* plexus.

From the Lias β (*obtusum, oxynotus*, and *raricostatum* zones), two specimens are figured by Bartenstein and Brand (1937, pl. 3, figs. 35–36). Their fig. 36, with four well-developed and two obsolete ribs, corresponds to our Form F; and their fig. 35, with two main and two degenerate ribs, corresponds to our Form I. These specimens were referred by Bartenstein and Brand to *Frondicularia baueri* Burbach and *Frondicularia bicostata* d'Orbigny, respectively.

Several specimens are figured by the same authors from the Lias γ (*jamesoni, ibex*, and *davoei* zones). Their pl. 4, fig. 50, shows a many-ribbed form referred to *Frondicularia sulcata* Bornemann, which corresponds to our Form K; their pl. 4, fig. 49 (*Frondicularia baueri* Burbach), has six ribs and represents our Form F; and their pl. 4, fig. 48 (*Frondicularia bicostata* d'Orbigny), has two firm and two degenerate ribs and corresponds to our Form I.

From the Lias δ (*margaritatus* and *spinatus* zones), a form assigned by Bartenstein and Brand to *Frondicularia terquemi* d'Orbigny (pl. 5, fig. 38) corresponds to the smooth forms occurring in the *davoei* zone and Middle Lias of Britain. *Frondicularia bicostata* d'Orbigny (pl. 5, fig. 40) has two ribs and is similar

PLATE 1

Evolution of the *Frondicularia sulcata* plexus in the Lower Lias. All forms are on H. M. Geological Survey slide no. Mik. (M) 458020.
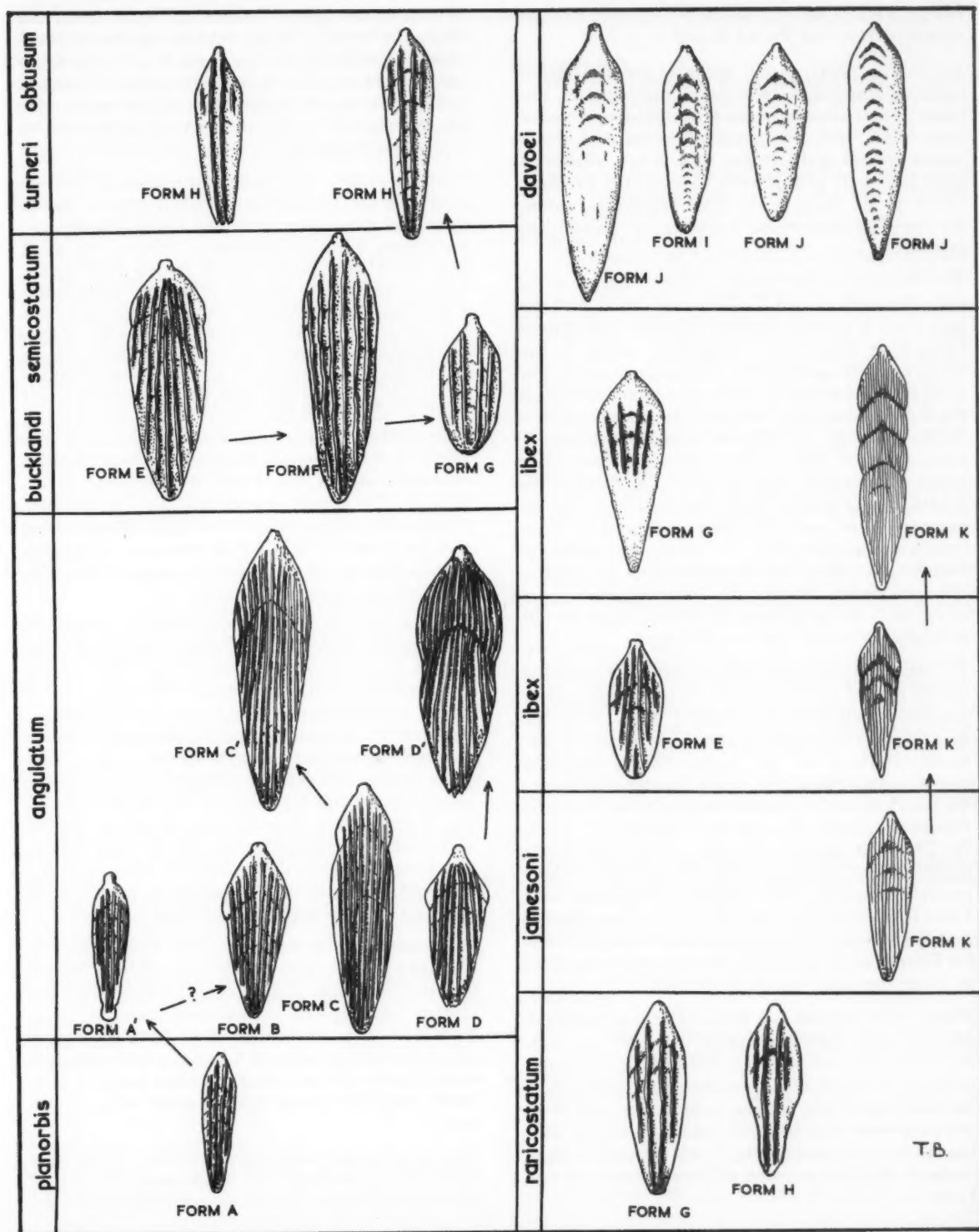
to our Form H, whereas their *Frondicularia baueri* Burbach (pl. 5, fig. 41 a–b) has six or seven ribs and corresponds to our Forms E and F.

Macfadyen (1941, p. 60) discusses the difficulty of differentiating between some of these species, and states: "On a broad basis of comparison, *Frondicularia sulcata* with *Frondicularia bicostata* and *Frondicularia terquemi* of d'Orbigny form a very closely related group. It is of interest to note that Berthelin (1879, p. 32) came to the same conclusion, calling the two last-mentioned varieties of *Frondicularia pulchra.*"

The difficulty is due largely to the confusion of the early Forms B, C and C' (*angulatum* zone) with the later Form K (*raricostatum* to *davoei* zones). All of these forms have been called *Frondicularia sulcata* Bornemann or *Frondicularia pulchra* Terquem or both. The study of the whole range of the species plexus through the Lower Lias has, it seems clear, resolved this problem, though difficulty still remains in differentiating Forms C and C' from Form K. *Frondicularia sulcata* Bornemann and its synonym *Frondicularia pulchra* Terquem were both described from the *davoei* zone, and the early Forms C and C' must clearly be another species or variety. The return of *Frondicularia sulcata* (i.e., Form K) after an absence of many-ribbed forms, and their apparent separation from the main evolving plexus, must be due to migration of this form into this area.

To return to the work of earlier authors, Bornemann (1854) figured and described two new species, *Frondicularia sulcata* and *Frondicularia dubia*, from the *davoei* zone of Göttingen. *Frondicularia sulcata* (Bornemann, 1854, p. 37, pl. 3, fig. 22 a–c) has nine straight longitudinal ribs, which become obsolete on the last chamber; it compares well with our Form K. *Frondicularia dubia* (Bornemann, 1854, p. 37, pl. 3, fig. 23 a–c) is figured with nine or ten ribs, which diverge at the initial end of the test and show a short central costation. This almost corresponds with Form E, with seven or nine ribs. It may be suspected that Bornemann's drawing is at fault here, and that his form is an intermediate stage, well exemplified at about the same horizon in Britain.

Blake (1876) figured two forms. The first, from the *bucklandi* and *capricornus* zones (pl. 19, fig. 22), shows six ribs with divergent initial ends. Although referred to *Frondicularia terquemi* d'Orbigny, it is probably our Form E. The second, from the *planorbis, angulatum* and *bucklandi* zones (pl. 19, fig. 23), has twelve fine, parallel ribs; it was referred to *Frondicularia sulcata* Bornemann, and is identical with our Form C.

Crick and Sherborn (1891) figured four species belonging to this group. *Frondicularia rugosa* (Crick and Sherborn, 1891, pl. 1, fig. 34) has nine coarse, irregular ribs, and may be our Form F or a near intermediate. *Frondicularia delirata* (Crick and Sherborn, 1891, pl. 1, fig. 37) shows curved ribs converging toward the aperture, and is clearly equivalent to our Forms D and D'.

Burbach (1886), in a paper on species of *Frondicularia* from the Middle Lias (*davoei* to *spinatus* zones), described a number of ribbed forms. *Frondicularia multicostata* Terquem (Burbach, 1886, p. 50, pl. 2, figs. 42–43) is a specimen with twelve parallel ribs, which corresponds to our Form K. *Frondicularia baueri* (Burbach, 1886, pl. 2, figs. 48–52) and *Frondicularia procera* (Burbach, 1886, pl. 2, figs. 54–55) are the intermediate Forms E and F. *Frondicularia bicostata* d'Orbigny (Burbach, 1886, pl. 2, figs. 56–57) is figured as having four to two ribs.

Both Klähn (1921, pl. 5, figs. 36–38) and Schick (1903, pl. 6, figs. 16–17) figured forms with four ribs corresponding to our Form H. Terquem (1862, pl. 5, fig. 13) described and figured a species called *Frondicularia sulcata* which is entirely different from that proposed in 1854 by Bornemann. Terquem's form is smooth, and the figure agrees closely with *Frondicularia terquemi* d'Orbigny.

Tappan (1955, p. 33) comments upon the evolutionary sequence shown by me (Barnad 1950*a*) as occurring in the *Frondicularia sulcata* group. She includes *Frondicularia squamosa*, a form not belonging to that group, and then draws attention to the fact that the range of this form, a many-ribbed species, overlaps that of *Frondicularia terquemi*, a smooth species. Tappan's species *Frondicularia squamosa* is probably the same as our Form K, although in Tappan's pl. 27, figs. 8 and 9, two very different forms are shown, and it is difficult to understand why she has put these forms together when throughout the work there is a repeated tendency to establish new species, often based on only the slightest variation.

An example of this tendency is the form figured in Tappan's pl. 27, figs. 11–19, showing the "new" species *Frondicularia lustrata*, every form of which has already been figured or described from the European Lias. It is abundantly clear from the figures that, in Alaska as well as in Europe, similar variation took place in the end members of the species group, where transition forms with four or with no ribs occur.

The zonation by species of *Frondicularia* is not only applicable in England, but holds good for most of the Lias of Europe. The cosmopolitan nature of the

foraminifera of the Lias (not only those belonging to the genus *Frondicularia*), supplemented by the forms shown by Tappan, suggests that when a more complete study of the Liassic foraminifera of Alaska is made as more material becomes available, and when a reasonably detailed ammonite succession is established there, then it will be found that the ranges of the species are close if not identical to those of Europe.

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PLATE 2

Forms of the *Frondicularia sulcata* plexus in the Lower Lias in H. M. Geological Survey boring, Stowell Park, Northleach, Gloucestershire, England. All specimens × 45.

1 Form A, 2020–2010 feet, *planorbis* zone.

2 Form A′, 1950–1940 feet, *angulatum* zone.

3 Form C, 1950–1940 feet, *angulatum* zone.

4–5 Form B, 1950–1940 feet, *angulatum* zone.

6 Form C′, 1910–1900 feet, *angulatum* zone.

7 Form D, 1910–1900 feet, *angulatum* zone.

8 Form G, 1630–1620 feet, *turneri* zone.

9, 22 Form E: 9, 1630–1620 feet, *turneri* zone; 22, 1320–1310 feet, *raricostatum* zone.

10 Form F, 1630–1620 feet, *turneri* zone.

11–12 Form H, 1410–1400 feet, *raricostatum* zone.

13–14, 20, 23 Form I: 13–14, 1400–1390 feet, *raricostatum* zone; 20, 1010–1000 feet, *ibex* zone; 23, 1090–1080 feet, *ibex* zone.

15–17 Form K: 15, 1390–1380 feet, *raricostatum* zone; 16, 1090–1080 feet, *ibex* zone; 17, 1320–1310 feet, *raricostatum* zone.

18–19, 21 Form J, 1010–1000 feet, *ibex* zone.
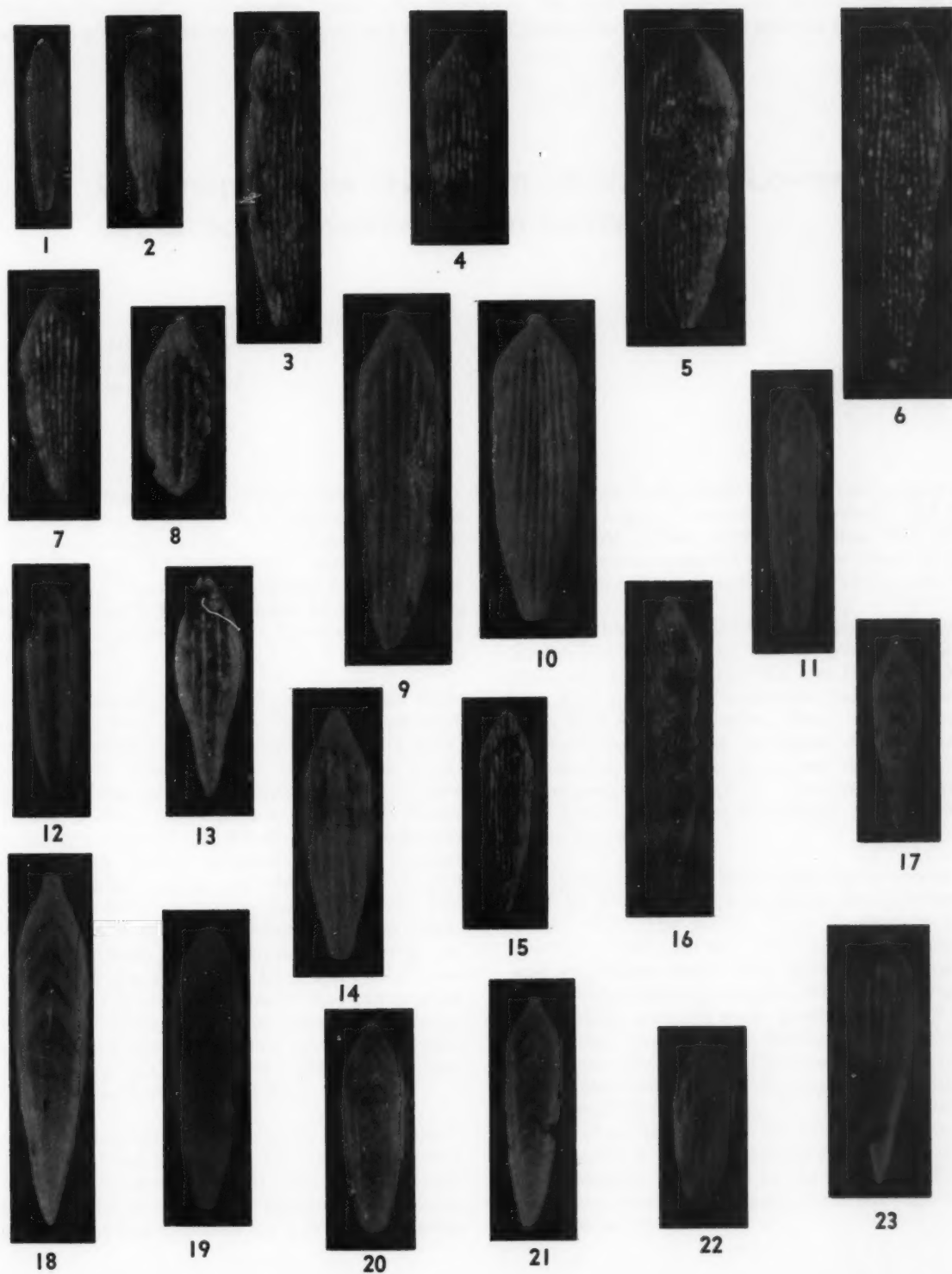
ABSTRACT: Coscinophragma cribrosum *was found in a rock specimen from the Regenbolshorn, Adelboden (Canton Bern), in the area of the ultrahelvetic Tothorn – Sex Mort nappe. The sample had been labelled "?Cenomanian," but the association of* Coscinophragma cribrosum *with true Urgonian foraminifera in this limestone proves its Urgo-Aptian age.*

Coscinophragma cribrosum (Reuss) in a Lower Cretaceous limestone from Switzerland

WOLF MAYNC

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A sample containing *Coscinophragma cribrosum* (Reuss) has been given to me by Wolf Leupold, Professor of Micropaleontology at the Swiss Federal Institute of Technology (ETH) in Zürich (sample Leupold no. 42047). The specimens figured in the present note (text-figs. 1–3) are deposited in the collections of the Micropaleontological Laboratory of that institute.

The rock sample, a brownish-gray zoogenic limestone, came from an exposure on the northern slope of the Regenbolshorn, Adelboden, Canton Bern, Switzerland. This rock lies between the transgressive Wang beds (Maestrichtian) and the Upper Jurassic Malm. The sample also contains *Dictyoconus walnutensis* (Carsey), *Dictyoconus* n. sp., *Coskinolina sunnilandensis* Maync, *Choffatella decipiens* Schlumberger, *Trocholina alpina* Leupold, representatives of the genera *Orbitolina, Pseudocyclammina, Lituola, Neotrocholina,* and other foraminifera, as well as *Salpingoporella mühlbergi* (de Loriol), Bryozoa, *Nerinea*, etc. (Maync, 1955 *a, b*). Both the litho- and the biofacies suggest an Urgonian limestone. It may be remarked that many specimens of the foraminifera present show a thin coating of brownish calcite(?), and some of them form nuclei of oolites of the same material (redeposition in biostromal talus).

Coscinophragma cribrosum has hitherto been considered an Upper Cretaceous form. The original specimen found by Reuss was derived from the Schillingen beds and the lower "Pläner" limestone (Cenomanian) of Biliny and Weißkirchlitz in Bohemia, Czechoslovakia, and the same form has been reported from the Upper Cretaceous of Germany and the Netherlands (Hofker, 1928; Thalmann, 1951). The occurrence here recorded extends the range of *Coscinophragma cribrosum* into the Lower Cretaceous.

Referring his form originally to the phylum Bryozoa, Reuss (1846) first placed it in the genus *Lichenopora* Defrance, 1823, and described it as *Lichenopora cribrosa*. After the study of numerous additional specimens from Saxony, however, Reuss (1871) arrived at the conclusion that *Lichenopora cribrosa* was a foraminifer, and hence he erected the new genus *Polyphragma*, which, because of its close relationship with *Lituola* (*Placopsilina* d'Orbigny), was allocated to the Lituolidae.

The generic name *Coscinophragma* was proposed in 1951 by Thalmann as a substitute for *Polyphragma* Reuss, 1871. The generic name *Polyphragma* had previously been used for a genus of annelid worms, and *Polyphragma* Reuss, 1871, is therefore a homonym of *Polyphragma* Quatrefages, 1865. *Coscinophragma* is one of the normally sessile genera assigned to the labyrinthic group of the family Placopsilinidae, which was subdivided by Cushman (1927) into the subfamilies Placopsilininae, displaying simple chambers, and Polyphragminae, characterized by labyrinthic chambers. Because the name *Polyphragma* is preoccupied as a generic term and was replaced by *Coscinophragma*, the name of the subfamily Polyphragminae also was changed to Coscinophragminae (Thalmann, 1951).
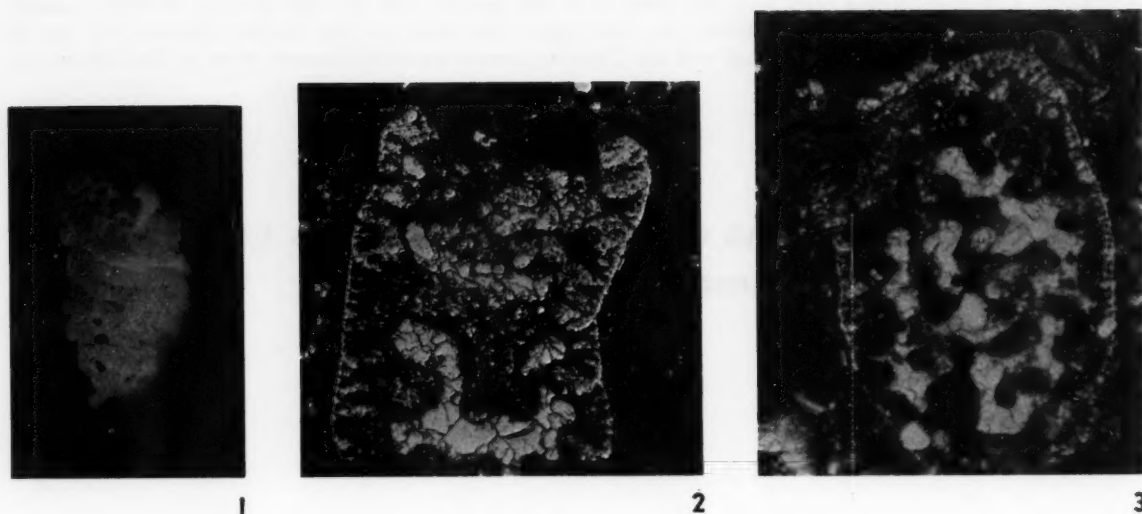
TEXT-FIGURES 1–3

Coscinophragma cribrosum (Reuss); Urgo-Aptian, Regenbolshorn (Adelboden), Switzerland: 1, external view, × 8; 2, longitudinal section showing labyrinthic wall structure with external impregnation of calcitic material and irregularly contoured chamber cavities, × 32; 3, transverse section displaying the same interior features, × 32.

SYSTEMATIC DESCRIPTION

Family PLACOPSILINIDAE

Subfamily COSCINOPHRAGMINAE

Genus COSCINOPHRAGMA Thalmann, 1951

Coscinophragma cribrosum (Reuss)
Text-figures 1–4

Lichenopora cribrosa REUSS, 1846, Verst. böhm. Kreideform., pt. 2, pp. 60, 123, pl. 14, fig. 10; pl. 24, figs. 3–5.

Polyphragma cribrosum (Reuss). – REUSS, 1871, K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzber., vol. 64, pt. 1, p. 278. – REUSS, 1872, Palaeontographica, vol. 20, pt. 1, fasc. 4, p. 139, pl. 33, figs. 8–10. – PERNER,1892, Česká Akad. Cisaře Františka Josefa, Třída 2, Pal. Bohemiae, no. 1, p. 18, pl. 1, figs. 1–14.

Coscinophragma cribrosa (Reuss). – THALMANN, 1951, Eclogae Geol. Helv., vol. 43, no. 2, p. 221.

Coscinophragma cribrosum (Reuss). – POKORNÝ, 1954, Základy zool. mikropal., p. 126, text-fig. 107.

The original diagnosis of the genus *Polyphragma* Reuss, 1871 (genotype: *Lichenopora cribrosa* Reuss, 1846), subsequently replaced by *Coscinophragma* Thalmann, 1951, is as follows (free translation from Reuss, 1871, p. 278): "The siliceous-arenaceous test is short, more or less cylindrical, sometimes a curved tube. The attached end of this tube may be flattened, whereas the other end shows a slightly convex cribrate terminal septum. At irregular intervals, the test exhibits concentric lines or grooves that mark the position of interior transverse partitions, which likewise show cribrate perforations and subdivide the interior cavity into chambers. The latter are, however, not simple, but, due to the ingrowth of very irregular, often anastomosing projections, display a coarsely cellular structure, the meshes of which harbored the living protoplasm.

"Except for the transverse partitions, the Recent genus *Botellina* shows the same features. A complete agreement of structure is recognized in *Lituola* (sensu stricto), which is, however, not attached and exhibits a spirally coiled initial portion. The fossil in question, which I designate *Polyphragma cribrosum*, therefore represents, so to speak, the attached straight part of a *Lituola*."

Additional remarks on *Coscinophragma cribrosum* were made by Perner in his paper of 1892 (written in Czech), which contains the supplementary statements that the test is usually free but sometimes attached, with bifurcations; that it is subdivided into annular segments by external sutures that correspond with labyrinthic protuberances or septa that extend into the interior; that the test in its adult stage is composed of twenty-two chambers; and that from nine to twenty-five openings, arranged at random or in two or three circles, form the terminal aperture. According to Perner (1892), the test is composed of an arenaceous layer consisting of angular sand grains 0.04–0.1 mm. in diameter, which are held together by a calcareous cement, and a thin
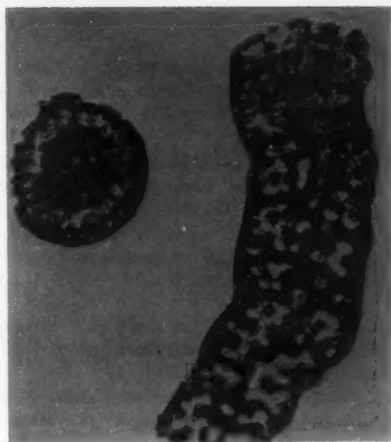
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TEXT-FIGURE 4

Coscinophragma cribrosum (Reuss); Upper Cretaceous, Kamajk (after Pokorný, 1954, p. 126, text-fig. 107); transverse and longitudinal sections, × 10.

porous layer composed of a calcareous hyaline substance which overlies the arenaceous wall to a large extent (Perner, 1892, pl. 1, figs. 13–14). This superficial layer is also reported to coat the irregular processes projecting into the chamber cavity (Perner, 1892, pl. 1, fig. 13). This hyaline layer is said to be perforate, being traversed by small passages which may reveal a funnel-shaped widening at the surface of the test.

It is evident from the figures given by Perner (1892) that this perforate hyaline coating forms the outer layer, although many textbooks have spread the erroneous concept that the inner layer is composed of this hyaline substance (Cushman, 1927, 1948; Colom, 1946; Sigal, 1952; Pokorný, 1954). The specimens described by Hofker (1928) from the upper Senonian of Maastricht show a well-developed initially coiled portion. Because of the projections extending inward, the chamber lumina show irregular contours, but the structure of the walls and septa is compact, not labyrinthic, and there is no inner perforate layer developed.

Our study of thin-sectioned specimens from the Regenbolshorn reveals a thick arenaceous wall which often contains numerous dichotomously branched passages running at right angles to the periphery of the test (labyrinthic wall structure). The outline of the cavities is irregular because of the processes that project inward from the walls and septa. Occasionally, the chamber cavities become almost completely obliterated by such ingrown material.

As for the presence and character of the so-called outer "hyaline" layer, we have the impression that it is not justified to speak of a double-layered wall structure as depicted rather schematically by Perner (1892, pl. 1, figs. 12–14). First of all, such a "hyaline" external layer is very often completely absent (see Perner, 1892, pl. 1, figs. 9–11; Pokorný, 1954, text-fig. 107). After the study of several thin sections, we tend to believe that the light-colored peripheral layer is a secondary impregnation, since the calcitic ("hyaline") material often fills all the passages and cavities of the labyrinthic wall structure. It is not the "hyaline" layer that is perforated by pores, but the labyrinthic channels are filled with the same whitish material that also forms the thin epidermal imperforate coating of the test. We have not observed that this calcitic material of the peripheral wall also lines the projections that reach from the walls into the chamber cavity.

The allocation of the present specimens to the genus *Coscinophragma* is still somewhat questionable, since by far the greater part of the specimens hitherto included in *Coscinophragma* (formerly *Polyphragma*) show irregularly contoured labyrinthic chambers, but neither the walls nor the septa seem to possess a truly labyrinthic (spongy) structure. According to Hofker (1928), however, such a labyrinthic interior wall structure is also evident in a specimen figured by Franke from Germany. Only an examination of Reuss' original material can reveal whether the genus *Polyphragma* was erected for forms showing simple arenaceous walls and septa, or for forms which, in addition to the presence of irregular (labyrinthic) chambers, disclose a genuinely labyrinthic wall structure with dichotomously branched passages.

Coscinophragma cribrosum is the only valid species of the genus. The form described as *Polyphragma variabile* (d'Orbigny) by Beissel (1891, pl. 4, figs. 46–48), from the Upper Cretaceous of Aachen, differs greatly from the genus as conceived by Reuss. It possesses an agglutinated-chalky initially coiled test and a simple aperture with a tooth. On this account, and because of its conical helicoid spire, this form has been referred to the valvulinid genus *Ataxogyroidina* (Marie, 1941). *Coscinophragma codyense* (Fox), described as *Polyphragma codyensis* from the Upper Cretaceous of Wyoming (Fox, 1954), is a coarsely arenaceous *Haplostiche*-like form. Nothing is known about its interior structure, and, in our opinion, the assignment to the genus *Coscinophragma* is highly questionable. "*Polyphragma* sp." was listed and figured by Cushman (1946, pl. 15, figs. 15–16) from the Austin, Taylor, and Navarro (Senonian) of Arkansas and Texas.

Coscinophragma is readily differentiated from other normally sessile arenaceous fossil foraminifera, such as *Acruliammina, Bdelloidina, Haddonia, Labyrinthina, Manorella, Stacheia, Thomasinella*, and the like, by its truly cribrate aperture.

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ABSTRACT: *Study of the type specimens of the foraminiferal species* "Rotalia" deeckei *Franke, 1925, indicates that it belongs to* Thalmanninella *Sigal, 1948, which is here regarded as a subgenus of* Rotalipora *Brotzen, 1942. The evolutionary relationships of* Rotalipora, Thalmanninella *and related forms are also discussed.*

The generic position of Rotalia deeckei Franke, 1925

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In a recent article (Dalbiez, 1955), *Rotalia deeckei* Franke, 1925, was placed in the group of *Globotruncana ventricosa*. This classification was made on the basis of Franke's type figures (see text-fig. 5a–c) and description (Franke, 1925, pp. 90–91, pl. 8, fig. 7a–c). Recently, through the kindness of Dr. Wehrli, Franke's type specimens were placed at the disposal of the author. Study of these forms has forced the writer completely to alter his former opinion regarding the classification of *Rotalia deeckei*.

The holotype of *Rotalia deeckei* is not definitely known. Two slides of this species are present in Franke's collection at Greifswald University. One slide is marked "*Rotalia deeckei* n. sp., Turon, Schwefelkiestone, Jordanshütte, Wollin." This specimen, though broken, is probably the holotype. The age and locality agree with that given by Franke with his original description of the form. The other slide is marked "*Rotalia deeckei* n. sp., schwarze Kreide, Wollin," with a pencil notation of "Gault." The Gault specimen is figured here (text-figs. 1–4) because the Turonian specimen is broken and incomplete. However, examination of the two specimens, together with Franke's detailed description, leaves little doubt that they are identical.

"*Rotalia*" *deeckei* undoubtedly belongs to *Thalmanninella*, and is probably of upper Cenomanian age. The last two secondary apertures on the umbilical side are very distinct (see text-fig. 2). The question then arises where it should be classified in relation to the subgenera of *Globotruncana*.
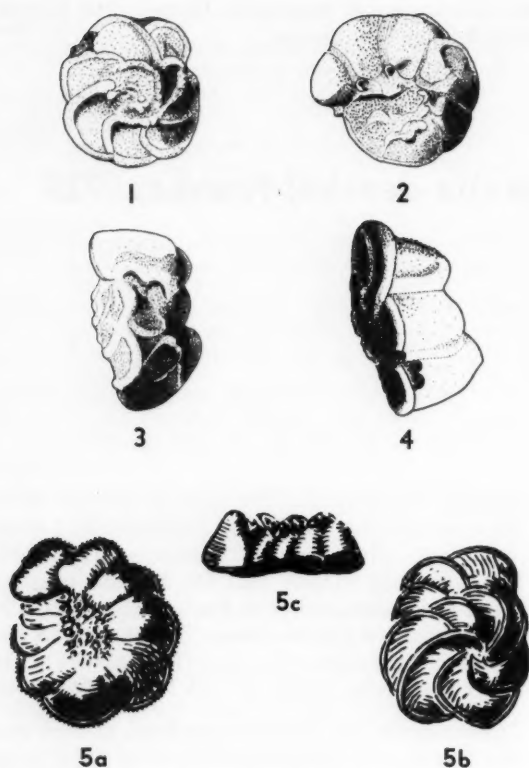
In January, 1949, Dr. Brotzen sent Professor Reichel five specimens of this form. One is a topotype from the Jordansee locality. The other four are from Nemitz, Pommerania. The slides of all five specimens are labelled "*Rotalipora (Thalmanninella) deeckei* (Franke)," with the age notation "Turonian." It is interesting to note that Dr. Brotzen acknowledged the generic status of *Rotalipora* and the subgeneric rank of *Thalmanninella*. The same view was expressed by Professor Reichel (1950, p. 600). The writer also favors a generic rank for *Rotalipora*.

Thalmanninella was described by Sigal in 1948 as a new genus, with *Thalmanninella brotzeni* Sigal as the genotype. A restudy of the holotype of *Globorotalia greenhornensis* Morrow, 1934, by Bronnimann and Brown (1956) showed that it belongs to *Thalmanninella* and is conspecific with *Thalmanninella brotzeni*, over which it possesses nomenclatural seniority. However, the writer does not agree with Bronnimann and Brown when they suggest that *Thalmanninella ticinensis* (Gandolfi) and *Rotalipora appenninica alpha* (Gandolfi) are the same as *Thalmanninella greenhornensis*. These three forms can be distinguished from one another with little difficulty.

Thalmanninella probably evolved from *Ticinella* by the development of the keel up to the last chambers, inasmuch as the keel is faintly visible on the early chambers of *Ticinella*. The writer does not feel that this simple development of the keel is sufficient reason for the assignment of generic rank to either *Ticinella* or *Thalmanninella*. He prefers to leave them in subgeneric rank, which appears more logical from a phylogenetic, taxonomic, or stratigraphic point of view.

In a similar manner, *Rotalipora* is related to *Thalmanninella*. Early forms of *Rotalipora*, such as *Rotalipora appenninica alpha*, possess thalmanninelloid aper-

mann and Brown does not appear logical when one considers that *Praeglobotruncana delrioensis* appears stratigraphically before *Rotalipora appenninica*. On the other hand, it appears probable that *Thalmanpinella greenhornensis* (= *brotzeni*) evolved from *Rotalinora appenninica typica* Gandolfi, 1942, through its end-form, *Rotalipora appenninica globotruncanoides* Sigal, 1948. Thus we would have the following evolutionary line: *Thalmanninella ticinensis* → *Rotalipora appenninica* → *Thalmanninella greenhornensis*.

This solution seems quite unsatisfactory to the writer, especially if we consider *Thalmanninella* as a valid genus. Inasmuch as studies are now being carried out toward a better classification of these forms, it appears that, for the present at least, Reichel's 1950 classification, that is, with *Globotruncana* and *Rotalipora* as genera and with *Ticinella* and *Thalmanninella* as subgenera of *Rotalipora*, should be retained.

"Rotalia" deeckei is probably a link in the evolution of a species of *Rotalipora* to a species of *Thalmanninella*. The specimen here figured (text-figs. 1–4) shows the transition of the secondary apertures, which are still quite distinct at the ends of the sutures. The species shows a strong affinity to *Rotalipora appenninica gamma* (Gandolfi), the end-form of which is *Rotalipora appenninica reicheli* Mornod, 1950. It will be necessary to determine the position of the secondary apertures of *Rotalipora apenninica gamma* in order to decide whether *Rotalia deeckei* is a senior synonym of that form or is, instead, another one of the many transitional forms of the *appenninica* group.

TEXT-FIGURES 1–5

"Rotalia" deeckei Franke, 1925; Franke collection, Greifswald University, no. 45, "schwarze Kreide, Wollin." 1, spiral side; diameter 0.473 mm.; × 51. 2, umbilical side, showing two secondary apertures; × 54. 3, front view; thickness 0.215 mm.; × ca. 135. 4, rear view; × ca. 146. 5a–c, reproduction of Franke's type figures 7a–c; × 42.

tures. These accessory apertures open into the umbilicus, and it is only in later species that they migrate into the sutures. This observation reinforces the theory, disputed by Bronnimann and Brown, that *Rotalipora* evolved from *Thalmanninella*. As a matter of curiosity, the writer wonders how *Rotalipora appenninica* could have originated from *Praeglobotruncana delrioensis* (Plummer) (= *Globotruncana stephani* Gandolfi, 1942). This suggestion by Bronni-

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Spirally designed picking tray

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Since picking microfossils from a sample is a time-consuming task, any improvement in the efficiency of this operation is of interest to micropaleontologists. The conventional picking tray is rectangular in outline and marked with a grid pattern. The picker moves the tray in one direction until the end of the row is reached, then moves the tray up or down to the next row and proceeds in the opposite direction. The inherent discontinuity of this operation is removed if, instead of a grid, a spiral pattern is employed in a round tray (see text-fig. 1). The picker rotates the tray in one direction (say, counter-clockwise) and, starting from the center, examines or removes the microfossils as they appear between two successive lines of the Archimedean spiral in one continuous operation.

Testing of the spiral tray has brought out other advantages. If the tray is inadvertently moved, this fact is not always apparent to the picker working with a grid, as the pattern is uniform throughout, whereas the curvature of the spiral is different in various portions of the tray, and such a movement is therefore more apt to be noticed. Also, if the picker pauses momentarily in the operation when using a grid, he sometimes forgets whether he was moving to the right or to the left when he stopped. This difficulty cannot occur with the spiral-patterned tray, as there is only one direction of movement. Experience in laboratory work at Columbia University indicates that the spiral tray considerably shortens the time necessary to pick micropaleonthological samples.

The techniques described in this paper were developed while the author was working at the Lerner Marine Laboratory, Bimini, B.W.I.
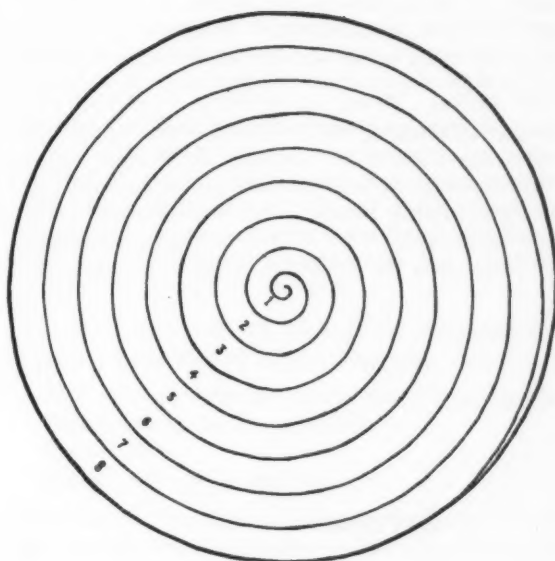
TEXT-FIGURE 1

The spiral tray is simple to construct. It should be circular for ease of rotating. The spiral may be drawn freehand or made more accurately by geometric construction. A single radius may be drawn and the spirals numbered as points of reference. The spiral should be spaced so that two lines of the spiral are encompassed in the microscope field. The proper spacing can be determined by placing a ruler in the microscope field. If more than one magnification is used it is desirable to have picking trays with appropriately spaced spirals.

Preparation of microfossils for photography

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Under this heading, Cummings (1956) described a useful method involving the application of silver nitrate for the darkening of foraminifera prior to photographic reproduction. In this connection, attention is drawn to a publication of Triebel (1947). Triebel's excellent photographs of ostracodes and foraminifera have always been the envy of micropaleontologists. In this publication, he discusses the preparation of microfossils and the necessary equipment. A major part of his paper deals with the application of photography in the service of micropaleontology, particular attention being paid to the problem of obtaining an adequate depth of field.

Glassy, transparent tests of foraminifera and ostracodes are difficult to photograph. Triebel shows with illustrations how a short heat-treatment can produce striking results. With heat-treatment and subsequent application of malachite green, followed by immersion in glycerine, Triebel brought out details of ornamentation which could not be observed on the untreated specimens. When heat and dyes are unsuccessful, a dark surface may often be the solution to the problem. For this purpose the specimen is immersed for a few seconds in a 5 to 20 per cent solution of silver nitrate, then dried on blotting paper and quickly heated on platinum foil. The result should be a deep brown to black coating. If an undesired metallic gloss results, then, the solution applied was too strong. Triebel's illustrations also show the effect of this treatment.

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Errata

In the paper by Alfred Traverse entitled "Systematic methods for Mesozoic and Cenozoic plant microfossils" (Micropaleontology, vol. 2, no. 4, pp. 396–398, October, 1956), there is an error in Table 1, column 3 ("Methods of illustration"). Under the name Sen, the phrase "Magnification not listed" should be replaced by *"Magnifications:* 150, 580, 640."

In the paper by Esteban Boltovskoy entitled "Applications of chemical ecology in the study of the foraminifera" (Micropaleontology, vol. 2, no. 4, pp. 321–325), the second sentence in the first paragraph of the right-hand column on p. 321 should read: "However, a thorough study of all the specimens encountered in the abundant material collected, including those whose state of preservation permitted only generic determination, revealed a total of 148 forms (species, subspecies and indeterminate species) from the Gulf of San Jorge, 104 forms from San Blas Bay, and 144 forms from the estuary of the Rio de la Plata, for example." The editors regret that, due to a misunderstanding, the sentence was unfortunately printed in its present erroneous form.

A multilingual foraminiferal dictionary

The Department of Micropaleontology, American Museum of Natural History, has just received a copy of the recently published "Diccionario foraminiferológico plurilingüe" by Dr. Esteban Boltovskoy (1956, Argentina, Minist. Marina, Direc. Gen. Navegac. e Hildrograf., S. H. Pub. Misc. no. 1001, Buenos Aires, 196 pp.). This book is the product of many years of labor, and represents, so far as known, the first attempt to compile a dictionary of this type for foraminiferal terms. Dr. Boltovskoy is, of course, eminently qualified for this task, for besides being a specialist in the foraminifera, he is well versed in all of the five languages covered.

The expressed purpose of this dictionary is to aid persons working on the literature of the foraminifera in English, Spanish, German, French, and Russian. In order to accomplish this aim, Dr. Boltovskoy has compiled a list of 2090 words and phrases, showing their equivalents in the five languages that are predominant in the foraminiferal literature.

The dictionary is composed principally of technical terms used in foraminiferal papers, rather than of those found in the paleontological and zoological literature in general. When a word or phrase has several meanings, the author gives only the equivalent of the one used in the foraminiferal literature, in order to avoid the cumbersome collection of words and phrases that might result if the entire synonymy of each term were included.

The main body of the dictionary consists of a list of terms in English arranged alphabetically, each term being given a serial number. Equivalents in Spanish, German, French, and Russian are given for each word or phrase listed. There are also separate indexes for the Spanish, German, French, and Russian terms, each of which is referred back to its equivalents in the main body of the dictionary by means of the serial number. This feature aids materially in expediting the search for any given word.

The editors of "Micropaleontology" believe that this book will be an invaluable aid to everyone concerned with problems of translation, editing, preparation of manuscripts, or research in connection with the foraminifera. It will not only supply the answer to many questions involving language problems, but it will also increase the scientific vocabulary of anyone using it.

The dictionary can be obtained in exchange for papers on all aspects of oceanography, from:

Dirección General de Navegación e Hidrografía
Departamento de Oceanografía
Lavalle 1634
Buenos Aires, Rep. Argentina.

It represents the first published contribution from the Foraminiferal Laboratory of the Department of Oceanography at Buenos Aires, of which Dr. Boltovskoy is in charge.
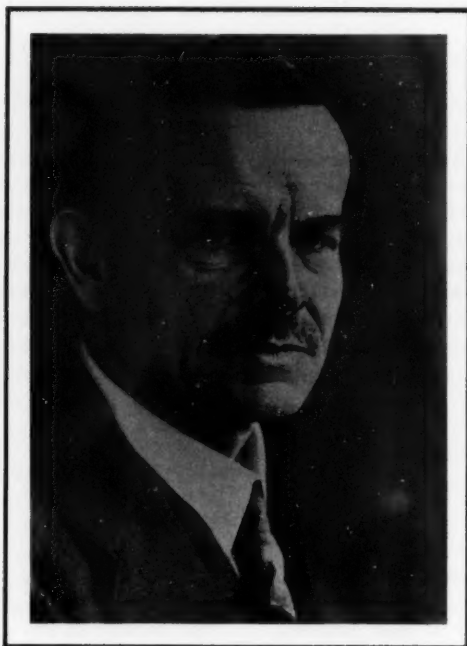
Rudolf Richter – 1881-1957

It is with profoundest regret that we are standing by the grave of Rudolf Richter, who was born on November 7, 1881, in Glatz, Silesia, and who died in Frankfurt on Main on January 5, 1957. Until the last day, even while he was ill, he directed all his energy toward paleontological work, and no one will ever be in a position to realize fully the great extent of his efforts to introduce objectivity into science.

Dr. Richter was not only the head of the Geological and Paleontological Institute of the University of Frankfurt on Main, but also Director of the Senckenberg Museum, editor of the journal "Senckenbergiana Lethaea," and founder of "Senckenberg am Meer" in Wilhelmshaven. In addition, he was the first president of the Paläontologische Gesellschaft, reorganized in 1948. His membership in the International Commission on Zoological Nomenclature was also of decisive significance.

His motto in life was: "Der Gewinn des Ganzen setzt nicht die Überwindung, sondern die Durchdringung des Einzelnen voraus." This point of view motivated his interest in micropaleontology and the establishment of a micropaleontological research department in the Senckenberg Museum. He also invited the submission of micropaleontological dissertations. As a result of his personal initiative, and under his supervision, papers of basic importance were written concerning the foraminifera and ostracodes of the Lower and Middle Jurassic and the Lower Cretaceous, and on the ostracodes and biostratigraphy of the Devonian and Middle Jurassic.

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RUDOLF GRILL

The following report on activities in the field of micropaleontology in Austria during 1956 is arranged alphabetically according to the names of the micropaleontologists concerned.

E. Kamptner, who works in the Department of Geology and Paleontology of the Museum of Natural History in Vienna, is continuing his studies of Coccolithinaeae. He recently published a paper entitled "Zur Systematik und Nomenklatur der Coccolithineen" (1956, Österr. Akad. Wiss., Math.-Naturw. Kl., Anzeiger, no. 1), and another on a species of *Thoracosphaera* from the Eocene of France (1956, Österr. Bot. Zeitschr., vol. 103, pp. 448–456). He has recently been awarded the title of Professor.

W. Klaus, of the Geological Survey of Austria, proposed, in a verbal communication, a preliminary scheme for the subdivision of the Upper Permian and Lower Triassic on the basis of palynology. He has also published a contribution to the stratigraphy of the younger Tertiary lignites of Carinthia, based upon the same type of work (1956, Austria, Geol. Bundesanst., Verh., pp. 250–255). He has succeeded in improving the methods of extracting pollen from salt-rock and phosphorite.

Klaus Küpper, Jr., has completed his studies of Upper Cretaceous smaller foraminifera and has published a paper on a standard section in the Gosau Basin (1956, Austria, Geol. Bundesanst., Jahrb., vol. 99, pp. 273–320). The Gosau formation (alpine Upper Cretaceous) near the type locality ranges in age from the lower Senonian up to and including the Paleocene. The boundary between the Coniacian and the Santonian is not apparent on the basis of the microfaunas, but the Campanian and Maestrichtian can easily be distinguished by their species of *Globotruncana* and *Pseudotextularia*. The presence of the Danian is dubious, and the problem of the Danian-Paleocene boundary is discussed. The systematic part of the paper covers all the species found in the section sampled. In 1956, Küpper left Austria to take up paleontological work in Nigeria.

R. Oberhauser, of the Geological Survey of Austria, has published a note on the microfaunas of some Rhaeto-Liassic marls near Salzburg (1956, Austria, Geol. Bundesanst., Verh., pp. 275–283). He has also published papers on the age of the so-called "Nierenthaler beds" (an alpine Upper Cretaceous foraminifera-bearing formation) at the type locality west of Salzburg (1957, Austria, Geol. Bundesanst., Jahrb., vol. 100, pp. 67–79), and on a new species of *Kilianina* and a new subgenus of *Trocholina* from Turkey (1956, Geol. Ges. Wien, Mitt., vol. 48, pp. 193–200, 2 pls.). At present he is studying Middle Triassic species of *Trocholina* from the Carnic stage of the northern Alps of Austria.

A. Papp, of the Institute of Paleontology of the University of Vienna, has completed his revision of the occurrences of orbitoids so far reported from Austria. He has published a paper on the orbitoids of the Upper Cretaceous flysch of the "Wienerwald" (1956, Austria, Geol. Bundesanst., Verh., pp. 133–142, 1 pl.). Here again, it has been found that the Campanian and Maestrichtian faunas are clearly distinguishable. A table indicating the stratigraphic distribution of the species of *Orbitoides* and *Lepidorbitoides* is included.

Along more classical paleontological lines, W. J. Schmidt has published a remarkable monograph on the Tertiary worms of Austria (1955, Österr. Akad. Wiss., Math.-Naturw. Kl., Denkschr., vol. 109, no. 7, pp. 1–121, 8 pls.).

A. Tollmann, of the Geological Institute of the University of Vienna, who has been working for some years on the younger Tertiary of the easternmost part of Austria (Burgenland), recently reported the occurrence of foraminifera in the marginal facies of the Tortonian (1955, Österr. Akad. Wiss., Math.-Naturw. Kl., Sitzber., vol. 164, pp. 193–202). He has also presented some arguments in favor of maintaining the distinction between the genera *Lingulina* and *Lingulinopsis* (1954, Österr. Akad. Wiss., Math.-Naturw. Kl., Sitzber., vol. 163, pp. 609–619).

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Geological Survey of Denmark

In T. Sorgenfrei's Department of Well Records (Borearkivet), Arne Buch is establishing a collection of microfaunal assemblages from Mesozoic and Cenozoic sediments in Denmark. He has published a paper on "The marine interglacial beds at Inder Bjergum; Foraminifera and stratigraphy" (in Danish with abstract in English) (1955, Dansk Geol. Foren., Meddel., vol. 12, no. 6). Arne Dinesen is studying the foraminifera of the Cenozoic section at Bregning, on Vejle Fjord in western Denmark.

In the Department of Palynology (Moselaboratoriet), the leader, J. Iversen, in collaboration with his associates, is engaged in obtaining material from important Danish pollen horizons for radiocarbon analyses. In 1954, Iversen published a paper entitled "The late-glacial flora of Denmark and its relation to climate and soil" (Danmarks Geol. Unders., ser. 2, no. 80). Alfred Andersen is now studying pollen from raised-bog deposits in Jutland. In 1954 he published a paper entitled "Two standard pollen diagrams from south Jutland" (Danmarks Geol. Unders., ser. 2, no. 80). Harald Krog, whose paper on a "Pollen analytical investigation of a C^{14}-dated Alleröd-section from Ruds-Vedby" appeared in the same volume, is currently working on late glacial and postglacial pollen from Denmark. Svend T. Andersen contributed a paper on "A late-glacial pollen diagram from southern Michigan" to the volume cited above; he is now studying the pollen stratigraphy of interglacial and glacial strata of Denmark. Peter Ingwersen is engaged in a survey of Paleozoic and Mesozoic pollen and spores from Danish well samples, and is studying pollen of the Cenozoic lignites of western Denmark; he contributed a paper on "Some microfossils from Danish late-Tertiary lignites" to the volume cited above. Another paper which appeared in the same volume was a study by Margaret S. Bryan, entitled "Interglacial pollen spectra from Greenland."

Harald Krog is also working with Professor Valdemar M. Mikkelsen, of the Royal College of Agriculture in Copenhagen, on a palynological examination of cores from the bottom of the Baltic Sea. This investigation is being carried out in close collaboration with Swedish geologists. Professor Mikkelsen contributed a paper entitled "Studies on the sub-Atlantic history of Bornholm's vegetation" to the 1954 volume cited previously.

National Museum, Copenhagen

The leader of the Palynological Laboratory (Nationalmuseets Moselaboratorium), J. Troels-Smith, and his associates, Svend Jörgensen, Bent Fredskild, and B. Brorson Christensen, are now engaged in archeological work. Recently they have been studying Swiss prehistoric lake dwellings and Paleo-Eskimo culture strata from Sermermiut in western Greenland. Some of the results are incorporated in a paper by Troels-Smith entitled "Pollenanalytische Untersuchungen zu einiger schweizerischen Pfahlbauproblemen" (1955, Das Pfahlbau-Problem (1954), Schaffhausen). In 1954, Jörgensen published a paper on "A pollen analytical dating of Maglemose finds from the bog Aamosen, Zealand" (Danmarks Geol. Unders., ser.2, no. 80), and Brorson Christensen had a note on "New mounting media for pollen grains" in the same volume.

Danish-American Prospecting Company

Aksel Nörvang has left DAPCO, which for a number of years was a Gulf Oil subsidiary. Nörvang has recently completed a major paper, "The foraminifera of the Lias series in Jutland, Denmark," which has been accepted by the University of Copenhagen as a doctoral dissertation.

University of Copenhagen

Assisted by grants from the Museum of Mineralogy and Geology and the Danish State Research Foundation, J. C. Troelsen has established a small micropaleontological laboratory. Because of the limited enrollment in the School of Geology, there are at present only a few graduate students taking courses in micropaleontology, and the laboratory is therefore engaged mainly in pure research. Troelsen is currently working on planktonic foraminifera of the pre-Pleistocene formations of Denmark, and he is also completing two small articles, on Robertinidae and on Jurassic Ceratobuliminidae. During the past few years he has published a number of papers, among which may be mentioned "Studies on Ceratobuliminidae (Foraminifera)" (1954, Dansk Geol. Foren., Meddel., vol. 12, no. 4), "Paleocaen nord for Mariager Fjord" (1954, ibid.), "Notes on *Ceratobulimina* and *Allomorphina*" (1955, Cushman Found. Foram. Res., Contr., vol. 6, pt. 2), "*Globotruncana contusa* in the White Chalk of Denmark" (1955, Micropaleontology, vol. 1, no. 1), and "Internal structure and systematic position of the foraminifer *Cerobertina*" (1956, Pal. Soc. India, Jour., vol. 1, no. 1).

Troelsen has recently returned from a study tour of North America, where he visited micropaleontologists in New York, Washington, New Orleans, Baton Rouge, La Jolla, Los Angeles, Palo Alto, San Francisco, Berkeley, and Mexico City. He wishes to convey his gratitude to the numerous fellow-workers whose cooperation, assistance and hospitality contributed largely to the success of his tour. The staff of Petróleos Mexicanos made special arrangements for the micropaleontologists participating in the Twentieth International Geological Congress, and Troelsen wishes to take this opportunity to thank them.

J. C. TROELSEN
Mineralogisk-Geologisk Museum
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S. R. N. RAO

Early in 1956 we welcomed Professor M. F. Glaessner of the University of Adelaide, Australia, who came to India under the Colombo Plan. He visited the micropalaeontological laboratories of the Universities of Lucknow, Banaras, and Mysore; of the Assam Oil Company at Digboi; and of the Geological Survey of India at Calcutta. At Lucknow he gave two stimulating talks, one on "Oil exploration" and the second on "Recent trends in micropalaeontology." He also held discussions with students of micropalaeontology, on the correlation of the Tertiary rocks of western India. At the Geological Survey of India, he helped in reorganizing the micropalaeontological laboratory. His visit to India was of great benefit to micropalaeontologists.

Another distinguished visitor, at present in Lucknow as visiting professor at the Birbal Sahni Institute of Palaeobotany, is Professor Gunnar Erdtman, Director of the Palynological Institute at Stockholm.

Assam Oil Company Ltd., Digboi

Workers at the palaeontological laboratory have been carefully studying the frequencies of the arenaceous foraminifera occurring in the Barail succession in the twenty wells drilled so far in Nahorkatiya. They have found that two horizons can be recognized on the basis of high frequencies of *Haplophragmoides* and *Trochammina*. These horizons have provided a basis for approximate correlation. A peculiarity of most of the Nahorkatiya wells is the abundant occurrence of small spherulites throughout the upper part of the Barails.

It has been found that foraminifera with ferruginous coatings show their characters better after boiling in a weak solution of potassium cyanide. The boiling can be repeated if necessary. This may be of interest to fellow micropalaeontologists.

Bose Institute, Calcutta

A. K. Ghosh and his coworkers have re-examined nineteen samples from the "pre-Cambrian" Vindhyan rocks of Peninsular India for microfossils. Of the samples examined, five belong to the Kaimur series of the Upper Vindhyans, and the rest to the Semri series of the Lower Vindhyans. Following the usual process of maceration in Schultze solution, with every possibly precautionary measure against laboratory contamination, the results arrived at are as follows: One sample of Bijaigarh shale, one of Olive shale, and two of Porcellanite are barren. Microfloras were found in one sample of Upper Quartzite, in one of shale of the Rohtas stage, and in one of the Kajrahat limestone. They are very meagre and consist of carbonized wood elements with or without pits, and primitive types of simple spores. In the rest of the samples, microfossils are abundant and comprise different types of carbonized wood elements with various types of thickening, cuticles and spores. The spores recovered may be classifies into:
A. Spores without a slit of dehiscence (Aletes)
   a) Azonaletes
   b) Microreticulatae
B. Spores with a slit of dehiscence (Monoletes)
   a) Punctatazonomonoletes
C. Spores with triradiate slit of dehiscence (Triletes)
   a) Leiotriletes
   b) Zonotriletes
   c) Microreticulati sporites
D. Spores with wings or bladders (Saccate)
   a) Monosaccites
   b) Allisporites
   c) Disaccites striatites.

The saccate spores occur abundantly in four samples from the Kheinjua stage, and very sparsely in one sample from the Rohtas limestone and in one from the Kajrahat limestone. Trilete spores occur in abundance in both the Rohtas and Kheinjua stages and very rarely in the Lower Kaimur; they are completely absent from the Basal stage (Lower Vindhyans) and Upper Kaimur (Upper Vindhyans).

From the results achieved, it can be generalised that well developed vascular plants of the archegoniate group (Pteridophyta, pteridosperms and gymnosperms) thrived in the Vindhyan era. Comparisons with the microfloras recorded from the Cambrian rocks of the Punjab Salt Range, Kashmir, and the United States, which have been worked out in the palaeobotanical section of this Institute, indicate that the Kheinjua and Rohtas stages are middle Upper Cambrian in age. The Basal and the Porcellanite stages of the Semri series are now considered to be Lower Cambrian, and the Upper Vindhyans, with their three series, are late upper post-Cambrian (Ordovician to Devonian) in age.

Standard Vacuum Oil Company, Calcutta

Detailed palaeontological examinations of the Cretaceous-Tertiary sequence of the South Shillong Front and of the Tertiary sequence of the Barail Range in Assam were continued. Additional occurrences of *Hantkenina alabamensis* and of *Cribrohantkenina bermudezi* were noted in the Upper Eocene of the Garo Hills. Earlier records of *Hantkenina alabamensis* are from the Rupa Ghara section (Biswas, 1954) and from the Therria section (Nagappa, 1956).

Interesting foraminifera from the Upper Cretaceous of the Therria section, in addition to those reported by Nagappa in 1956, are: *Frankeina taylorensis, Marssonella oxycona, Rectogümbelina cretacea, Globigerina cretacea, Pseudouvigerina plummerae, Nodosaria affinis, Palmula primitiva, Frondicularia* cf. *verneuiliana, Ramulina* cf. *navarroana, Ramulina* cf. *arkadelphiana,* and *Bulimina* cf. *kicka-*

pooensis. The foraminiferal assemblages resemble those of the Taylor marl of the United States, and are of Campanian to Maestrichtian age. A rich hystrichospherid assemblage was also encountered in the same section. Rich Eocene (Lutetian) spore and pollen assemblages from the Garo Hills were found to compare with those described from the Eocene of Venezuela as described by Norem.

A study of the Barjipada beds of the Burha Balang River section has revealed the presence of a moderately rich foraminiferal fauna. The foraminifera are very minute, indicating a restricted habitat. The species are closely similar to those described by Cushman from the tropical Pacific. The fauna indicates a Pliocene or Pleistocene age.

J. N. Dorreen, who has been Chief Geologist for Standard Vacuum in India for the last two years, has carried on foraminiferal and other stratigraphic studies. He returned to Esso Standard in October of 1956.

Benton Stone contributed substantially toward the reorganization of the palaeontological laboratory in Calcutta during a three-month assignment. B. Biswas is palaeontologist-in-charge. S. K. Bakshi and B. Sahay are other palaeontologists working at the laboratory. D. J. Carter and D. D. Bayliss were visitors.

Birbal Sahni Institute of Palaeobotany

K. R. Surange and K. M. Lele have obtained a rich microflora from the Talchir Needle shales (Giridih coal field), which have hitherto been regarded as unfossiliferous. Talchir shales from another locality (South Rewah Gondwana Basin) have also yielded a large number of spores. These are under investigation. Investigations are also continuing on coals from India and Europe. S. C. D. Sah has described a large number of microspores from the Jurassic shales of the Salt Range.

D. C. Bhardwaj has two papers in press. The first is entitled "Palynological investigations of the Saar coals" (Palaeontographica, ser. B, vol. 101). A total of 109 spore species are taxonomically treated, of which fifty-six species are new. The second paper is entitled "The spore flora of the Velener-Schichten (Lower Westphalian D) in the Ruhr coal measures." The taxonomic section of this paper covers sixty-six spore species, referable to thirty genera, of which two genera and thirteen species are new.

Lucknow University

S. R. N. Rao, B. S. Tewari, Krishna Mohan, and A. K. Chatterji have a paper in press in the Geological Magazine, entitled "The Miocene of western India." The paper deals mainly with the correlation of the Miocene beds of western India with those of Ceylon, Indonesia, and the Middle East, on the basis of larger foraminifera.

A. R. Rao has been studying fern sporocarps found in a silicified block from the Deccan inter-trappean (Eocene) series. These sporocarps are probably the microsporocarps of *Azolla inter-trappeana,* the megasporocarps of which were described in detail by the late Professor Birbal Sahni. A. R. Rao has also been continuing his studies of the microfossils in some of the Palana lignites (Eocene). Various types of fungal hyphae, spores, and other parts have been found. The basal part of a small filamentous alga referable to *Oedogonium,* and fragments of uniseriate filamentous algae of probable ulotrichalean affinity, have also been found.

Krishna Mohan and A. K. Chatterji have recently published a paper entitled "Stratigraphy of the Miocene beds of Kathiawar (western India)" (1956, Micropaleontology, vol. 2, no. 4, pp. 349–356). The Miocene beds are described and their stratigraphic position determined on the basis of the foraminifera contained in them. *Taberina* (= "*Orbiculina*") *malabarica* (Carter) is considered to be Burdigalian in age. Beds younger than Burdigalian are not present. The fauna shows Indo-Pacific affinities.

B. S. Tewari has published a paper on "The genus *Spiroclypeus* from Kutch, western India" (1956, Current Science, vol. 25). The paper records *Spiroclypeus ranjanae,* n. sp., from the Aquitanian. Tewari has also recently observed the presence of the characteristic Jurassic foraminifer *Aulotortus* in a dark gray pyritous limestone of the Patcham series (Bathonian) of the Habo Hills, Kutch. Other associated foraminifera are species of *Textularia, Bigenerina, Spiroplectammina,* and *Gaudryina.* Further investigations are in progress.

S. B. Bhatia and N. K. Mandwal are engaged in a study of smaller foraminifera from the Agate conglomerates (Miocene) of the Surat-Broach region, western India. L. Rama Rao has published a paper on "Recent contributions to our knowledge of the Cretaceous rocks of south India." The paper summarizes and elaborates the palaeontological and stratigraphic work done so far on the richly fossiliferous Cretaceous rocks of south India. The paper also lists the fossil algae and foraminifera reported from these beds.

S. R. N. RAO
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ITALY

ENRICO DI NAPOLI

During the years 1955 and 1956, micropaleontological activity in Italy was chiefly concerned with Tertiary foraminifera, although a few papers on Ostracoda were published.

Dr. F. Villa has studied samples from water wells drilled near Varese (Lombardy). He found foraminiferal assemblages referable to the Pliocene. These faunas show some analogies with those of other Pliocene outcrops of the Varesotto area. In a study of Tertiary outcrops south of Varese Lake (Lombardy), Dr. Villa found pelagic foraminiferal faunas of Eocene age, containing Globigerinidae and *Globorotalia*. Ecological studies of the "Gonfolite" formation in this area were also made.

Mrs. M. B. Cita Sironi has studied foraminiferal faunas from several stratigraphic sections and from a boring made by AGIP near Castenedolo (Garda Lake area). An attempt was also made to synthesize the paleogeography and geological history of this area. Lists of foraminifera were also given. Mrs. Cita also studied the microfauna of the argillaceous beds intercalated in the "Gonfolite" formation (Varesotto area), which made it possible to determine the Oligocene age of these beds.

On the occasion of the Fourth World Petroleum Congress, Mrs. Cita considered the problem of the transition between the Cretaceous and Eocene beds in Italy, on the basis of several stratigraphic and subsurface sections. The sequences examined consist of marly limestones (scaglia facies), which contain rich foraminiferal faunas. The transition between the Cretaceous and Eocene appears to be represented by continuous sedimentation, without an apparent lithologic break. The microfaunas, on the contrary, show a remarkable change. The faunal sequences, from top to bottom, are the following:

3) *Globorotalia velascoensis*, associated with large, thick-shelled Globigerinidae. This assemblage corresponds to the Paleocene.

2) Small, thin-shelled *Globigerina* and *Globigerinella*, associated with small *Gümbelina*. This assemblage corresponds to the Danian.

1) *Globotruncana stuartii* and *Globotruncana contusa*, associated with *Pseudotextularia varians*. This assemblage corresponds to the Upper Cretaceous (Maestrichtian).

The transition from Cretaceous to Eocene thus corresponds to the disappearance of the genus *Globotruncana*. The thin-shelled *Globigerina* fauna immediately overlying the Cretaceous beds with *Globotruncana* is considered to represent the Danian stage. This stage is always only a few meters thick and shows similar characteristics in all the sequences examined.

Mrs. Cita has also studied a sample of bottom mud obtained from Professor Picard's bathyscaph at a depth of 85 meters near the island of Capri (Tyrrhenian Sea); this sample shows about 10 per cent of planktonic individuals; benthonic species are scarce, with Rotaliidae, Textulariidae, Nonionidae, and Miliolidae predominant.

Miss M. Giunta has studied five samples of foraminifera collected in the Gulf of Genoa at depths ranging from 20 to 135 meters. The percentages of pelagic individuals were low in all cases (12 to 16 per cent). The predominant benthonic families found were the Miliolidae, Nonionidae, Rotaliidae, and Textulariidae. The occurrence of *Anomalina balthica*, *Bulimina marginata*, *Uvigerina mediterranea* and *Cassidulina laevigata carinata*, associated with a typical shallow-water assemblage, is notable. These species appear to have been widespread in the Mediterranean area at the beginning of the Pleistocene. Comparisons with Recent and Pleistocene foraminiferal faunas were made. One new species of foraminifera, *Quinqueloculina pentagona*, was described and illustrated.

Miss A. Farioli has studied a microfauna collected near Colle S. Colombano (Milan). This fauna contains a few species of *Cassidulina* and *Bulimina*, represented by numerous individuals, and is believed to represent a period of low water-temperature corresponding to the beginning of the Pleistocene.

Miss M. A. Ruscelli has published the first part of a micropaleontological study concerning a single stratigraphic section 200 meters thick, in the Piedmont region along the Mainia River (Asti). The microfossils found are foraminifera and Radiolaria. Typical foraminiferal assemblages indicating the Aquitanian, Langhian and Helvetian stages were found. Our knowledge of the foraminifera of the Aquitanian is very limited. The second part of this work, with several plates illustrating the most important species, is now in press in the "Rivista Italiana di Paleontologia" for 1956.

Mrs. C. Rossi Ronchetti has studied a foraminiferal fauna collected in the Piedmont region near Cuneo. The assemblage, which contains large species of *Siphonodosaria*, *Uvigerina barbatula*, and *Uvigerina rustica* associated with *Globoquadrina altispira*, is considered typical of the Helvetian.

Drs. F. Protodecima and F. Ferasin have described and illustrated the following new foraminiferal species and varieties from the Eocene of the Colli Euganei (Vicenza): *Pseudoclavulina euganea, Eggerella pulcherella, Karreriella marina, Karreriella termalis, Robulus bullatus* Hantken var. *carinatus, Ehrenbergina insueta,* and *Cibicides micrus* Bermudez var. *pusillus*. Dr. Ferasin has also studied samples from well no. 44 drilled to a depth of 818 meters by AGIP in the Podenzano gas field near Piacenza. A detailed study of the foraminiferal fauna was made, and statistical data on the composition of the foraminiferal assemblage were also presented. This study made it possible to distinguish lower Pliocene and Messinian beds unconformably overlying Langhian beds. The most important assemblages and species were illustrated in five plates. The new forms *Nonion dalpiazi* and *Entosolenia orbignyana* (Seguenza) var. *miocenica* were described and illustrated.

Miss E. Tamajo has studied samples of "brecciated clays" collected from many localities in central Sicily. These brecciated clays consist of clayey beds of Pliocene age that include heterogeneous materials of different lithologic types and ages. The fragments of the various lithologic types were segregated and then separately washed and studied. Microfossils of Lower Pliocene, Miocene, Eocene and Upper Cretaceous ages were observed. These brecciated clays are widespread in central Sicily and always show similar lithologic and faunal characters.

Dr. E. Perconig has studied and illustrated two new striated species of *Uvigerina, Uvigerina longistriata* and *Uvigerina striatissima,* from Neogene beds in northern Italy. Comparisons were made with other striated species of *Uvigerina,* and most of these species were illustrated. Dr. Perconig has also studied samples from wells drilled by AGIP near Castenedolo (Brescia). The study of the foraminifera indicated the presence of marine Pleistocene down to 535 meters; marine Pliocene sediments follow, extending down to 905 meters, and directly overlie Danian beds with predominant Globigerinidae and Globorotaliidae.

In connection with oil explorations carried on by AGIP in the Marche region, Dr. Perconig has also made a stratigraphic and paleontologic study in that area (1955, Boll. Servizio Geol. Ital., vol. 77). Foraminiferal assemblages of Pliocene and Miocene ages are described, and the stratigraphic distribution of more than 300 species is given. Statistical data concerning the faunal composition are also included in this work. One new species, *Orthomorphina stainforthi,* is described and illustrated.

B. Martinis and V. Conato have studied the Miocene of the Colli Veronesi and Vicentini (Veneto).

Some of the foraminiferal faunas found indicate the presence of the Helvetian stage.

Professor G. Tavani has studied samples from borings made in a search for salt deposits in Val Cecina (Tuscany). Foraminiferal faunas were found in clays interbedded with salt and gypsum. These faunas show a remarkable decrease in the number of species in comparison with those of a normal marine environment. A degenerative tendency was observed in the coiling of *Bulimina echinata,* and reduction in the size of specimens of *Rotalia beccarii.* A new species, *Bolivina dentellata,* is considered by the author to be typical of a high-salinity environment. The age of this fauna is considered to be upper Tortonian. In addition to *Bolivina dentellata,* the new species *Reussella tumida* is described and illustrated.

Professor E. Giannini has reported a rich foraminiferal fauna from near Pisa. The age of the fauna has been determined as lower Pliocene, and it is believed to represent a rather deep-water marine environment.

Professor E. Montanaro Gallitelli has studied samples containing fucoids and Helminthoidea collected near Modena in the Apennines, representing the "Argille scagliose." The presence of abundant specimens of *Schackoina* and *Gümbelina* made it possible to determine the age of the samples and to demonstrate the presence of Cretaceous beds in this area. A note concerning the stratigraphic variability and value and the geographic distribution of the genus *Schackoina* was published in volume 1, number 2, of "Micropaleontology." One new species, *Schackoina tappanae,* was described and illustrated.

Professor Gallitelli has also undertaken a revision of the foraminiferal family Heterohelicidae, which can be subdivided into two subfamilies, Gümbelitriinae and Heterohelicinae, on the basis of the coiling in the

early stage. Three new foraminiferal genera from the Upper Cretaceous *(Bronnimannella, Tappanina* and *Trachelinella),* belonging to the subfamily Heterohelicinae, are described and illustrated (1956, Cushman Found. Foram. Res., Contr., vol. 7, pt. 2).

Professor G. Ruggieri has published the second part of the iconography of the Pleistocene and Pliocene Ostracoda of Italy (1954, Atti Soc. Ital. Sci. Nat. Milano, vol. 93, fasc. 3–4). This work concerns the genus *Buntonia;* the various species found in Italy are described and illustrated. One new species and three new subspecies *(Buntonia subulata, Buntonia sublatissima dertonensis, Buntonia giesbrechtii robusta,* and *Buntonia subulata rectangularis)* are described and illustrated. A new genus, *Loculicytheretta,* with the genotype *Cythere pavonia* Brady, is also described and illustrated.

Professor Ruggieri has also completed a revision of the Ostracoda collected and studied by Neviani in 1928 (1956, Atti Soc. Ital. Sci. Nat. Milano, vol. 95, fasc. 2). These Ostracoda were included by Neviani in the genus *Cythereis,* and were subdivided into seven groups. Professor Ruggieri has revised their nomenclature and has proposed one new genus, *Carinocythereis,* with the genotype *Cytherina carinata* Roemer. This new genus is described and illustrated.

The micropaleontological activities of the oil companies working in Italy and Sicily have greatly increased during the past few years. AGIP Mineraria has built a group of important laboratories for oil research in San Donato Milanese near Milan. The micropaleontological laboratory has been transferred there, and several micropaleontologists are now working there. Subsidiary laboratories have also been set up in Sicily. The Somicem Company (of the E.N.I. group) has set up a micropaleontological

laboratory in Rome and subsidiary laboratories in the Abruzzi and Marche regions. So. di P.I. (Edison group) has set up two laboratories, one in Rome and one in Sicily. Montecatini and associated companies already have a micropaleontological laboratory and staff. Gulf Italia (formerly the American International Oil and Fuel Company) has increased the number of micropaleontologists in the Palermo laboratory.

Dr. F. Barbieri and V. Conato of AGIP Mineraria have been engaged by Gulf Italia in Palermo as micropaleontologists. Dr. E. Perconig of AGIP Mineraria, who was in Spain for a year, is now coming back to manage the new micropaleontological laboratory of AGIP in San Donato Milanese. Dr. A. Gianotti has resigned from Gulf Italia and has accepted a position with So. di P.I. (Edison) in Palermo. Professor E. di Napoli has resigned from Gulf Italia and has entered the consulting firm of M. P. Marchetti & E. di Napoli in Rome.

Mrs. E. Montanaro Gallitelli visited the United States and carried on micropaleontological research in the National Museum in Washington. The funds for her visit to the United States were provided by the Italian National Research Council and a Fulbright grant. Professor G. Ruggieri has transferred from the Geological Institute of Bologna to the Geological Institute of Palermo, where he is now in charge of geology. Professor B. Accordi, of the Geological Institute of Ferrara, has been named professor of geology in the University of Catania, where he is now reorganizing the Geological and Paleontological Institute. Miss M. A. Ruscelli has left the Geological Institute of Milan and has accepted a position as micropaleontologist in the Marchetti & di Napoli petroleum consulting firm in Rome.

ENRICO DI NAPOLI
Rome

MEXICO

CLEMENCIA TÉLLEZ-GIRÓN

The Nineteenth Session of the International Geological Congress, held in Algiers in September, 1952, voted to accept the invitation extended by the Mexican Government and to hold its following session, scheduled for 1956, in Mexico. The Twentieth Congress therefore took place in Mexico City, September 4–11, 1956, and was highly successful, thanks to the contributions of attending scientists and the efforts made by the organizers, all of whom had given freely of their time and energies for several months previous to the Congress. The Organizing Committee for this Congress appointed by the President of Mexico, Adolfo Ruiz Cortines, consisted of the following members: Presidente: Lic. Gilberto Loyo, Secretario de Economía Nacional; Vocales: Lic. Luis Padilla Nervo, Secretario de Relaciones Exteriores; Sr. Antonio J. Bermúdez, Director General de Petróleos Mexicanos; Dr. Nabor Carillo Flores, Rector de la Universidad Nacional Autónoma de México; Primer Secretario: Ing. Antonio García Rojas, Gerente de Exploración de Petróleos Mexicanos; Segundo Secretario: Ing. Eduardo J. Guzmán, Subgerente de Exploración de Petróleos Mexicanos.

The Organizing Committee, in its turn, established an Executive Committee, which was composed of the following members: Presidente: Ing. Antonio García Rojas, Gerente de Exploración de Petróleos Mexicanos; Secretarios Generales: Ing. Eduardo J. Guzmán, Subgerente de Exploración de Petróleos Mexicanos; Dr.

Genero González Reyna, Investigador del Instituto de Geología de la Universidad Nacional Autónomo de Mexico; Tesorero: Ing. Federico Mina Uhink, Jefe de Geólogos de Petróleos Mexicanos.

Under the presidency of Ing. García Rojas, the Congress planned its activities to include field trips for all attending members to various points of interest in Mexico, as well as regular sessions to be held at the new campus of the National University of Mexico. Papers to be read and discussed were grouped into fifteen sections and five symposia. Paleontology, taxonomy and evolution were coordinated by M. Maldonado-Koerdell and G. A. de Cserna, micropaleontology by H. E. Thalmann, and the symposium on the Cretaceous and its world relationships by L. B. Kellum. More than forty papers were presented on the subject of micropaleontology alone.

The Laboratory of Paleontology and Petrography of Petróleos Mexicanos, under the direction of X. Méndez Fernández and M. L. Robles Ramos, was visited by many distinguished persons, who had the opportunity of looking at samples from the various formations of eastern Mexico. The staff of Petróleos Mexicanos contributed the following papers: F. Bonet, *Microfaunal zonation of the Cretaceous;* F. Bonet and M. Trejo, *Radiolarian faunas in the phosporitic Jurassic rocks of the Sierra Madre Oriental in Santa Rosa, Zacatecas;* F. Bonet and A. Becerra, *The flora of Solenoporaceae of the Tertiary of Baja California;* Y. Eternaud, *On various Globigerinae of the Upper Cretaceous of Mexico;* C. Flores, *Presence of the genus Coleites Plummer, 1943, in the Paleocene of the Purísima-Iray basin in Baja California;* G. Moreno, *Tentative zonation of the Pliocene and Miocene of the Burgos Basin, Tamaulipas;* M. L. Robles Ramos, *The genus Eponidella in the Miocene of Tabasco and Campeche and in the Pliocene of northwestern Mexico;* M. L. Robles Ramos, C. Mordovich, and A. R. V. Arellano, *Foraminifera of the Fuente Superior, Rocallosa and Río Blanco formations and their relationship*

to the upper limit of the Cretaceous in Magallanes, Chile.

The Institute of Geology of the National University of Mexico, under the direction of Ing. G. P. Salas, has established a department of micropaleontology, with Biol. Augustín Ayala in charge of investigations. His personal contribution to the International Geological Congress was a paper on the paleontology of the Upper Cretaceous and Eocene of the Central Plateau of Chiapas, Mexico, written in collaboration with J. Alvarez, formerly of the Laboratorio de Paleontología de Petróleos Mexicanos.

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CLEMENCIA TÉLLEZ-GIRÓN
Petróleos Mexicanos
México, D. F.

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UNITED STATES — EAST COAST

ALFRED R. LOEBLICH, JR.

American Museum of Natural History
New York

The past year has been an exceedingly active one for the Department of Micropaleontology. Two new research projects, the rapid development of the quarterly "Micropaleontology," the completion of a new laboratory for the study of living and fossil foraminifera, and the expansion of the spore and pollen program, as well as a very full field season in the Long Island Sound project, have been added to the regular activities of the Department.

In September, 1956, the Department of Micropaleontology undertook two research projects for the Carter Oil Company of Tulsa, Oklahoma. One of these, under the direction of Brooks F. Ellis and Angelina R. Messina, relates to the study of microforaminifera. The other, which is directed by L. R. Wilson, is on the hystrichospherids. Each project is expected to run a minimum of one year. Hans Behm, Robert Popper, and Eugene Tynan are now employed full-time on these projects.

A new laboratory for the study of both living and fossil foraminifera has been completed and equipped. Work on the microforaminifera project and on the laboratory phase of the Long Island Sound project is already in progress in this new laboratory, while the hystrichospherid project and the spore and pollen research are carried on in an adjacent laboratory established last year.

The quarterly "Micropaleontology" developed rapidly during 1956, and at the end of the year had about one thousand subscribers. The mailing list is about equally divided between foreign and domestic subscribers. Substantially more manuscripts were received than were accepted for publication, and the quality of papers submitted has continued to remain high. Arrangements have been made recently to have the composition done by a printer in Germany, and a substantial saving in the cost of this item is anticipated.

Dr. L. R. Wilson has been made a Research Associate of the Department and has expanded his activities substantially.

New York University

The Department of Geology at New York University has expanded its offering to include the doctorate in micropaleontology. There are presently seven students who have matriculated for this degree, and thirty-five who are working for their master's degrees in micropaleontology.

Dr. Leonard R. Wilson joined the faculty of the Department of Geology as a full-time member of that group in September, 1956. His duties are primarily in the graduate school, but he also teaches one undergraduate class.

The Long Island Sound Project, which is run in cooperation with the Department of Micropaleontology of The American Museum of Natural History, got under way in the spring of 1956. Its objective is the study of sediments and sedimentation in the Sound, as well as of micro-organisms inhabiting the waters associated with these sediments. Special attention is being given to the radioactivity of the sediments.

The work is carried on from a converted Navy boat equipped for both remote control and aqua-lung operations. Darwin O. Hemer, a graduate student at New York University and a research assistant in the Department of Micropaleontology, American Museum of Natural History, is in charge of the boat. Mr. Hemer has been assisted by Richard Charmatz, Allen Steinberg, Stephan Podaras, William Gehrman, and a group of skin divers from one of the New York clubs. Radiometric work has been done by Fred Feigl, and the chemical analysis of sediments by Richard Kaplan. The project is under the direction of Brooks F. Ellis.

In the spring of 1956, Foster Smith, who has now returned to his position with Socony-Mobil in Venezuela, completed a study of Recent shallow-water foraminifera from Tarut Bay, Saudi Arabia, and Harold Cousminer completed a study on the evolution of *Operculina* based on material from Saudi Arabia. Mr. Cousminer is now engaged in work on polymorphism in several living and fossil foraminiferal populations. Josephine Sperrazza is working on the Cretaceous-Eocene boundary problem in Sicily, and Harry Leffingwell on the microfossils of the Vicksburg of Texas. Jerome Brock is completing a study of shallow-water and brackish-water foraminifera of Tampa Bay, Florida, and David Hughes one on the foraminifera of the Cyrenaican

Coast, northern Libya. Mr. Brock is now employed by American Overseas Petroleum, and Mr. Hughes by Esso Standard (Libya), both in Tripoli. Allen Westerholm, who is also with American Overseas Petroleum in Tripoli, has recently completed a study of the Middle Jurassic of central France. Fred Feigl, who is with the Sun Oil Company in Austin, Texas, has finished a study on the northernmost limit of living foraminifera in the Hudson River. Robert Popper has recently begun to work on the microforaminifera of the early Tertiary of the Gulf Coast. Emanuel Nieves, who is with the Dominion Oil Company in Trinidad, is continuing his study of foraminifera and type sediments of Lower New York Bay. Darwin O. Hemer has begun the task of correlating the Dammam and Rub' al Khali sections in Saudi Arabia. Peter Sciaky, who is employed in the New York office of Cerro da Pasco, is well along in his study of hystrichospherids from the Onondaga formation of eastern New York.

Smithsonian Institution (U. S. National Museum), Washington, D. C.

Alfred R. Loeblich, Jr., and Helen Tappan Loeblich are continuing their studies of foraminiferal genera, in connection with their work on the "Treatise on Invertebrate Paleontology." The genus *Pararotalia* Le Calvez has been revised, and a paper describing various species is at present in press. Two papers involving new genera of the Heterohelicidae were completed, a description of *Chiloguembelina* was published, and a paper describing a peculiar Paleocene form is in press. A revision of the planktonic genus *Globigerinita* Bronnimann is in press, with a description of a new Recent planktonic genus. In addition, the Loeblichs have in press a paper on the Paleocene and Lower Eocene planktonic foraminifera of the Atlantic and Gulf Coastal Plains. Another paper concerns correlations of the Paleocene and Lower Eocene of the Gulf and Atlantic Coastal Plains with type sections in Europe and else-

where, on the basis of planktonic foraminiferal zonation.

During 1956, numerous workers from foreign lands studied in the Museum for varying lengths of time. Among these were Saad E. Nakkady, University of Alexandria, Egypt; Alijandro Euribe, Empresa Petrolera Fiscal, Zorritos, Peru; Hans M. Bolli, Trinidad Oil Co., Ltd., Pointe-à-Pierre, Trinidad, B.W.I.; J. C. Troelsen, University of Copenhagen, Denmark; I. M. van der Vlerk, Rijksmuseum van Geologie en Mineralogie, Leiden, Netherlands; A. Debourle, S.N.P.A., Pau, France; J. B. Saunders, Trinidad Oil Co., Ltd., Pointe-à-Pierre, Trinidad, B.W.I.; Eugenia Montanaro Gallitelli, Modena, Italy; and Morton Polugar, Dominion Oil Co., Port of Spain, Trinidad, B.W.I.

Other visitors to the Museum included Robert Lagaaij, Shell Oil Co., Houston, Texas; Jerome A. Brock, American Museum of Natural History, New York; H. H. Winters, University of California, Berkeley, California; J. R. Bentor, Geological Survey of Israel; Lee B. Gibson, Creole Petroleum Corporation, Maracaibo, Venezuela; C. E. Dawson, Institute of Marine Sciences, University of Texas; F. M. Swain, University of Minnesota; A. A. Öpik, Bureau of Mineral Resources, Canberra, Australia; H. G. Kugler, Natural History Museum, Basel, Switzerland; Albert F. J. Smit, University College, Achimota, Ghana; F. Brotzen, Stockholm, Sweden; P. Brown, Raleigh, North Carolina; F. V. Stevenson, Houston, Texas; A. A. Olsson, Coral Gables, Florida; M. K. Elias, University of Nebraska; R. C. Moore, University of Kansas; A. W. Nauss, Calgary, Alberta Gordon Gunter, Ocean Springs, Miss.; Lynn Glover, Puerto Rico; T. W. Amsden, Oklahoma Geological Survey; Richard Cifelli, Harvard University; S. K. Fox, Rutgers University; R. K. Olsson, Princeton University; J. F. Schindler and G. A. Dickie, Pensacola, Florida; R. A. Zingula, Louisiana State University; and A. W. Marianos, Chico, California.

U. S. Geological Survey Washington, D. C.

Raymond C. Douglass has a manuscript in press on the foraminiferal genus *Orbitolina*. He is now engaged in a study of *Orbitolina* from the Caribbean area and South America and is expanding his study to include other genera of the Orbitolinidae. Ruth Todd and Doris Low are studying smaller foraminifera from drill holes in the Marshall Islands.

Wilbert H. Hass has completed papers on the age and correlation of the Chattanooga shale and the Maury formation of Tennessee, involving conodonts, and has in press a paper on conodonts from the Chappel formation of Texas. Hass' contribution to the "Treatise on Invertebrate Paleontology" has been completed and, in addition, was revised during the past year to include new data.

Kenneth E. Lohman is working on the Cenozoic nonmarine diatoms of the Great Basin and has completed a paper covering 400 species, about 100 of which are new. Harlan Bergquist has prepared a report on the Upper Cretaceous foraminifera of the Matanuska formation of Alaska and is now working on foraminifera from wells in Naval Petroleum Reserve 4, northern Alaska. Helen Tappan Loeblich is working on the description of Cretaceous foraminifera from Naval Petroleum Reserve 4, a continuation of the series published in U. S. Geological Survey Professional Paper 236.

I. G. Sohn has completed a section of the Ostracoda part for the "Treatise on Invertebrate Paleontology" and also has in press a paper on the Paleozoic species of *Bairdia* and related genera. He is at present continuing the revision of late Paleozoic ostracode genera and in 1957 is to begin a study of Lower Cretaceous ostracodes from Wyoming and South Dakota. During 1956, Sohn published two papers: One on Pliocene ostracodes from Jackson Hole, Wyoming, and one on the transformation of opaque calcium carbonate to translucent calcium fluoride.

Jean M. Berdan is working on the Lower Paleozoic ostracodes of the Great Basin and Rocky Mountain areas.

Princeton University
Princeton, New Jersey

Richard Olsson is engaged in a study of the foraminifera of the Red Bank formation (Upper Cretaceous) and the Hornerstown formation (Paleocene) of New Jersey. Both of these formations have excellent faunas of well preserved material and include many new forms.

Rutgers University
New Brunswick, New Jersey

S. K. Fox is engaged in a study of the foraminifera of the Vincentown formation of New Jersey, whose age has been the subject of much controversy. Richard A. Page is engaged in a study of the foraminifera of the Brightseat formation (Paleocene) and the Monmouth group (Upper Cretaceous) of Virginia and Maryland.

Harvard University
Cambridge, Massachusetts

Richard Cifelli is working on the Middle Jurassic foraminifera of Great Britain. Last summer was spent in field collecting, and Cifelli returned again this spring to continue his collecting and also to study types in the British Museum.

Cornell University
Ithaca, New York

E. Pessagno is engaged in a study of Upper Cretaceous *Globotruncana* from Puerto Rico.

McLean Paleontological Laboratory
Alexandria, Virginia

The McLean Paleontological Laboratory announces the publication of the "Frizzell-Exline Card Catalogue of holothurian sclerites," edited by Don L. Frizzell and Harriett Exline. The initial part of the catalogue is based upon their "Monograph of holothurian sclerites." Subsequent units will be issued as determined by the editors. This catalogue is being published with the hope that it will aid workers in paleontology in using these interesting fossils, which have considerable ecological value. Price and details of issue will closely follow the pattern established by the "McLean Card Catalogue of American foraminifera."

Facilities are available at the McLean Paleontological Laboratory for 1) a study program selected by the applicant, leading to publication of results by this laboratory or other suitable medium; 2) a study program under the guidance of the director, leading to publication of results; and 3) a training program designed to qualify the trainee for work as an oil company micropaleontologist. The laboratory gives neither academic credits nor job guarantees; the purpose of this offer is to assist persons who would like to become better fitted for oil company micropaleontological work.

Those who are interested in being placed on the notification list for publications of this laboratory, or who would like further information concerning the study and training programs, should write to James D. McLean, Jr., P. O. Box 916, Alexandria, Virginia.

ALFRED R. LOEBLICH, JR.
U. S. National Museum
Washington, D. C.

UNITED STATES — GULF COAST

STUART A. LEVINSON

Shell Development Company
Houston, Texas

Dr. Alfred Traverse, assisted by Lawrence Hinton, Jr., is currently engaged in fundamental research on spores and pollen from the Gulf Coast, which entails a study of the present flora. Blair S. Parrott, assisted by William Berggren and Miss Anne Anderson, is studying Recent foraminiferal faunas from the Gulf of Mexico and the occurrence of similar faunas in parts of the Tertiary.

R. Wright Barker has completed a paper entitled "Some notes on the age of the Tamesi-Velasco formation in Mexico," which was presented at the Twentieth International Geological Congress in Mexico City and will be published in the forthcoming "Symposium on the Cretaceous system and its world correlations." Dr. Barker has also completed a revision of the nomenclature of the foraminifera figured by H. B. Brady in the Atlas accompanying his Challenger Report. It is expected that this revision will be published next year, together with a facsimile reproduction of Brady's plates, as a special publication of the Society of Economic Paleontologists and Mineralogists. Dr. Barker is currently engaged in an investigation of Pleistocene foraminiferal faunas from the Louisiana subsurface.

D. F. Toomey is engaged in a study of arenaceous foraminifera, conodonts, and microscopic fish remains from the Pennsylvanian, but this work has not yet progressed sufficiently for the publication of any results. Dr. Jacob Schweighauser, who was on the laboratory staff during 1954 and 1955, has completed a paper entitled "Pelagic foraminifera from the Cretaceous of central and north Texas," and Dr. F. E. Lozo and Dr. F. L. Stricklin, Jr., have prepared a paper entitled "Stratigraphic revision of 'Travis Peak formation,' basal Cretaceous of central Texas." Both of these papers were presented at the Twentieth International Geological Congress in Mexico City and will be published in the forthcoming "Symposium on the Cretaceous system and its world correlations."

In addition to the intensive routine micropaleontological work being carried out by the various Area and

Division offices in the Gulf Coast, a number of more specialized studies have been undertaken. E. H. Rainwater, assisted by Robert Lagaay, Miss Julie Eastin, and S. J. Rosenfeld, are currently investigating the Miocene foraminiferal faunas in the Gulf Coast and their relation to facies. This work is being carried out by the Technical Services Division in Houston. The Corpus Christi Divisional Stratigraphic staff are working on environment studies in the Tertiary section involving the interrelationship of lithology and micropaleontology. Dr. George A. Sanderson, of the Midland Area, is studying Pennsylvanian Fusulinidae.

Agricultural and Mechanical College of Texas
College Station, Texas

T. J. Morris, a graduate student, is conducting a study of the foraminifera found in the Weches formation of San Augustine County, Texas. This study should be of particular interest because of the proximity of the Cane River type locality in western Louisiana. F. E. Smith, Professor of Geology at Texas A. & M., is describing the foraminifera found in several surface exposures of the Reklaw formation in southeastern Milam County, Texas.

Lamar State College of Technology
Beaumont, Texas

Henry Kane is beginning a research problem on the Sabine Lake area, in which he will make micropaleontological studies of the sediments of this area.

Rice Institute
Houston, Texas

The Geology Department at Rice Institute has begun work in micropaleontology only recently. However, fine laboratory arrangements for micropaleontological studies have been designed in the new building which is now under construction. There are at present four graduate students in micropaleontology, one of whom will carry on work with Dr. Carey Croneis with a view to publication. Dr. Croneis, assisted by William Huff, is engaged in a study of the micropaleontology of

a faunally rich basal shale lens of the Silurian Brownsport formation in Wayne County, Tennessee.

Southern Methodist University
Dallas, Texas

Dr. Claude Albritton is engaged in studies of the Lower Cretaceous stratigraphy of western Hudspeth County, Texas. He has completed a study of the foraminifera of the Cox and Finlay formations in their type areas. This material is to be included as part of a larger report on the Sierra Blanca area to be published in the future by the U. S. Geological Survey.

Texas Christian University
Fort Worth, Texas

Daniel Jarvis is making a stratigraphic study of the fusulinids of the Wolfcamp formation at its type locality. This work is being done in connection with doctorate research at Stanford University. Mr. Jarvis is assistant professor of geology at T.C.U. Stanley Slocki is presently collecting samples for microfossil study from the Weno-Pawpaw contact from Fort Worth northward to the Red River; his object is to check for any faunal reflection of the formational boundary. Mr. Slocki is a graduate assistant in geology, working toward his master's degree.

Texas Western College
El Paso, Texas

Emily Vowell has recently completed a study on foraminifera and Ostracoda of the upper Comanchean entitled "Microfauna of the Del Rio formation of Cristo Rey (Los Muleros) of Dona Ana County, New Mexico." Dr. Lloyd Nelson is working on microscopic gastropods from the Pennsylvanian of the Franklin Mountains of western Texas. Many other microfossil forms, such as foraminifera, sponge spicules, holothurian plates, and ostracodes, are associated with them. Excellent specimens of microcrinoids and ostracodes, as well as sponge spicules and holothurian plates and a few blastoids, have also been studied, from the Lake Valley limestone of

New Mexico. W. S. Strain, now on leave from Texas Western, has done some work on Devonian conodonts from the Franklin Mountains.

University of Houston
Houston, Texas

Gene Ross Kellough is continuing with research on the biostratigraphy of the lower Midway of Texas. Mrs. Kellough presented a paper on "Distribution of foraminifera around a submerged hill in the Gulf of Mexico" at the November meeting of the Gulf Coast Association of Geological Societies.

University of Texas
Austin, Texas

Miss Joan Echols is making a study of the smaller foraminifera, Ostracoda, and conodonts of the Strawn-Canyon boundary zone in both the Brazos River and Colorado River valleys. Miss Echols' work will be the basis of a master's thesis. George Cook has completed an analysis of the smaller foraminifera, ostracodes and conodonts of the middle Canyon beds, from the top of the Adams Branch limestone to the base of the Ranger limestone, in the Colorado River valley of central Texas. Dennis Drake is undertaking a micropaleontological and stratigraphic study of the smaller foraminifera, conodonts and ostracodes of Canyon and Cisco age in the interval from the top of the Ranger limestone through the top of the Gunsight limestone in the Colorado River valley area.

In 1956, Charles Morris completed a thesis on the foraminiferal faunas of the Del Rio shale from Del Rio, Texas, to Seguin, Texas, using both surface and subsurface information. Mr. Morris is now in charge of the micropaleontological laboratory of the American Overseas Petroleum Company in Turkey. James H. Pyne is writing a master's thesis on the problem of foraminiferal zonation of the lower Taylor strata in the Austin and Taylor areas in central Texas. Miss Lael Ely is completing a master's thesis on the reworked foraminifera of the Oakville (Oligocene) sandstone of the Coastal

Plains. Miss Ely's work is being carried on under the joint supervision of Professors S. P. Ellison and J. A. Wilson, and will be coordinated with the vertebrate interpretations of stratigraphic zonation developed by Professor Wilson. Professor Ellison is continuing his long-range study of the stratigraphic distribution of the conodonts of the Pennsylvanian of Texas. Up to this moment, the development of the work has been mainly in the Strawn and Canyon beds.

**Louisiana State University
Baton Rouge, Louisiana**

Dr. Laura Laurencich and Dr. H. V. Howe are working on Cretaceous Ostracoda and hope to complete a monograph on the known Cretaceous species in the not-too-distant future. Dr. Laurencich has just completed a paper on a new Lower Cretaceous ostracode genus, which has been submitted to the Journal of Paleontology. Oscar Paulson is working on the Ostracoda of the Austin chalk of Texas and its equivalents. Ronald Drouant is working on the stratigraphy and ostracodes of the Navarro group of southwest Arkansas. Robert Collins is working on the stratigraphy and Ostracoda of Taylor equivalents of southwest Arkansas. Robert Waldron, who is affiliated with the Coastal Studies Institute, is making a seasonal ecological study of the foraminifera of Timbalier Bay. Elvon Anderson is making a study of Jurassic Ostracoda in the subsurface of northern Louisiana. Richard Zingula is working on Upper Cretaceous foraminifera of the Sacramento Valley. Alan Cheetham is completing a study of the Bryozoa of the Ocala limestone of Florida. Carl Thorsen is working on the subsurface stratigraphy of Caddo Parish and the regional stratigraphy and Ostracoda of the Brownstown and Tokio formations.

**Florida Geological Survey
Tallahassee, Florida**

Harbans S. Puri has submitted two articles for publication, entitled "Reclassification, structure, and evolution of the family Nummulitidae," and "Recent Ostracoda from the west coast of Florida." He is at present working on the microfaunas of the Caloosahatchee marl and the Avon Park limestone.

**Florida State University
Tallahassee, Florida**

William Lapinski is conducting a study of the distribution of foraminifera in the shallow water of the northeastern Gulf of Mexico south of Dog Island and St. George Island. This is his master's thesis. The Zoology Department has a Ph.D. candidate working on Recent ostracodes in the northeastern Gulf of Mexico. At the Oceanographic Institute of Florida State University, Neil Hulings, under the direction of Harbans S. Puri, is studying the ostracode and foraminiferal populations of the Alligator Harbor and Apalachee Bay areas, in order to establish ostracode biofacies and subfacies.

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